June 22, 2017

Commonwealth of Virginia
Department of Environmental Quality
ATTN: Melanie D. Davenport
P.O. Box 1105
Richmond, Virginia 23218

Re: DEQ Request for Additional Information for Developing and Evaluating Additional Conditions for Section 401 Water Quality Certification for Interstate Natural Gas Infrastructure Project

Dear Ms. Davenport:

Please see the following response by Mountain Valley Pipeline, LLC (Mountain Valley or MVP) in regards to the Commonwealth of Virginia, Department of Environmental Quality's (DEQ) June 15, 2017 request for additional information for developing and evaluating additional 401 Water Quality Certification conditions for the upland construction activities associated with the proposed Mountain Valley Pipeline Project (Project).[1]

Permanent Right-of-Way Maintenance Measures

DEQ Information Request No. 1: Include a description of any ROW maintenance and inspection measures to be used in areas of slopes greater than 30 percent or include more detail in Section 6.0 of the Landslide Mitigation Plan.

Mountain Valley Response No. 1: A description of the ROW maintenance in steep slopes is stated in Section 5.3.1 of the Project Specific Standards and Specifications (S&S),[2] the slope gradients will be identified on the detailed site-specific erosion and sediment control plans (ESC Plans) in steep slope areas. An engineering geologist or geotechnical engineer will monitor construction in steep slopes areas and will have the authority to require the additional mitigation measures described in the Landslide Mitigation Plan (LMP), which was provided in the June 1, 2017 DEQ information request, Appendix 5. Minimum erosion and sediment control measures for steep slopes are specified in the approved S&S and include trench breakers, slope breakers, permanent seeding, and soil stabilizing blankets/matting (*see, e.g.*, Sections 2.5.1, 2.8.2, 2.9.2, 2.9.4, 3.5, 5.3.3), and additional measures may be deemed necessary in these areas based upon field conditions at the time of construction. The additional measures could include extra temporary and permanent slope breakers (Standard Detail MVP-17, S&S App. B), erosion control matting, and/or hydroseeding which will promote quicker vegetative coverage. In addition, Mountain Valley has increased the waterbar spacing requirements on slopes greater than 30% to 50-feet between each waterbar (Standard

[1] DEQ's June 15, 2017 letter includes attached meeting notes from a June 7 and 8, 2017 meeting between DEQ, other state and federal agencies, and representatives from Mountain Valley and the Atlantic Coast Pipeline. Those notes include a number of additional questions and comments that are not reflected in the Request for Additional Information addressed to Mountain Valley, and instead pertain only to the Atlantic Coast Pipeline. Accordingly, this letter responds only to questions in the Request for Additional Information specifically addressed to Mountain Valley.
[2] The S&S were approved by DEQ on June 20, 2017. Because the S&S are voluminous and now on file with DEQ, they have not been attached to this response.

Detail MVP-ES19).[3] Per the FERCs Upland Erosion Control, Revegetation, and Maintenance Plan, part V.B.2, the slope breakers (waterbars) "will remain in all areas, except cultivated areas and lawns, unless requested by the landowner using spacing recommendations obtained from the local soil conservation authority or land managing agency."

Inspection measures at steep slopes and all other areas will include one Lead Environmental Inspector (LEI) and at least one Environmental Inspector (EI) per construction spread. The LEI/EI will review the implementation of the S&S and coordinate with the Construction Supervisor about additional measures which may be needed to address erosion and sedimentation. The Project will have at least one DEQ-Certified ESC and SWM Inspector per construction spread. These inspectors may be the same LEI and EI described above or a DEQ-Certified ESC and SWM Inspector from a third party contractor. Mountain Valley may enter into agreements or contracts with soil and water conservation districts, adjacent localities, or other public or private entities to carry out or assist with these responsibilities.

Following construction, the engineering geologist or geotechnical engineer supervising construction will determine what additional maintenance and monitoring measures, if any, are necessary for each steep slopes based on site-specific conditions (LMP 10). Several locations (Peters Mountain, Sinking Creek Mountain, Brush Mountain, Giles County Seismic Zone) have already been identified for additional monitoring, including periodic inspections with the use of visual inspection and LIDAR to identify any indication of possible slope movement (LMP 24-25).

Hydrostatic Testing and Dust Control Protection Measures

DEQ Information Request No. 1: Explain if the water for dust control will be purchased from municipal sources, as with hydrostatic testing, or if other surface water sources will be used. The Fugitive Dust Plan states only that "water will not be withdrawn from streams for dust control". Explain if water will be directly withdrawn from any other surface water sources, such as lakes, ponds or quarries etc., to be used for dust control or other activities. Surface water withdrawals for all purposes, including dust control and HDD, of less than 10,000 gallons per day from non-tidal waters and less than 2 million gallons from tidal waters per day are excluded from VWP Permit requirements (9VAC25-210-310. A. 11).

Mountain Valley Response No. 1: Water for dust control and hydrostatic testing will be purchased from municipal sources. Mountain Valley has been coordinating with water suppliers to ensure there is adequate water to serve the area and Mountain Valley's usage requests during construction and testing. Surface withdrawals from streams, rivers, wetlands, reservoirs, ponds, or other impoundments will not occur with this project.

DEQ Information Request No. 2: If daily withdrawals from dust control or HDD exceed 10,000 gallons per day from non-tidal waters and 2 million gallons from tidal waters per day, a VWP Permit in accordance with 9VAC25-210 et. seq. is required.

Mountain Valley Response No. 2: Mountain Valley will not be conducting HDDs for this project. All water for dust control and hydrostatic testing will be purchased from municipal sources.

DEQ Information Request No. 3: Provide a drawing showing the proposed location of discharge areas for hydrostatic testing water.

[3] For comparison, the minimum spacing requirement for permanent waterbars on slopes greater than 30% in FERC's Upland Erosion Control, Revegetation, and Maintenance Plan, Part V.B.2, is 100 feet.

Mountain Valley Response No. 3: Appendix 1 contains the maps associated with the location of the hydrostatic discharges. In addition the location of the hydrostatic discharge points will be shown on the ESC Plans submitted to DEQ.

Riparian Buffer Protection

DEQ Information Request No. 1(a): MVP should state that removal of riparian buffers not directly associated with the project construction activities is prohibited.

Mountain Valley Response No. 1(a): Mountain Valley will add the following note to the approved ESC Plans: Clearing any areas outside of the permitted limits of disturbance (LOD) is prohibited.

DEQ Information Request No. 1(b): Disturbance and removal of riparian buffers from project related upland ground disturbing activities that would occur within 50 feet of any perennial, intermittent, or ephemeral surface waters should be avoided where possible, and minimized if 50 feet is not possible.

Mountain Valley Response No. 1(b): Mountain Valley will add the following note to the approved ESC Plans: Where possible, a 50 foot buffer will be maintained around all project area and adjacent area perennial, intermittent, or ephemeral surface water. In areas, where this buffer is not possible, only the minimal amount of disturbance will be conducted.

DEQ Information Request No. 1(c): Removal of riparian buffers shall not be allowed where stream bank stability under normal flow conditions would be compromised.

Mountain Valley Response No. 1(c): Mountain Valley has reduced LOD at stream crossings to 75-feet where possible. Riparian buffers will be protected and maintained to the extent possible. Potential impacts to streams and stream banks are minimized or eliminated by using instream diversions during construction, preforming constructing activities during low flows, avoiding the streams during seasonal restrictions, and/or using more stringent E&S BMPs around the resources. The streams will be restored to preconstruction conditions by using approved construction techniques. All stream banks are immediately stabilized and restored as soon as the pipeline is installed and the temporary crossing is removed. Using these construction techniques reduce the potential for stream bank failure and provides the opportunity to restore the bank to a more stabilized condition, if warranted.

Spill Prevention Control and Countermeasure (SPCC) Plan

DEQ Information Request No. 1: SPCC Plan should include information as referenced in Attachment B (Kimballton-Klotz Karst) page 10.

Mountain Valley Response No. 1: Referencing this information on the approved ESC plans would, as a practical matter, provide better information for the contractor and increase the protection of the resources. Therefore, Mountain Valley will add the following note on the approved ESC plans between mileposts 200.7 and 202.3: Any release to an identified karst feature between Mileposts 200.7 and 202.3 has the potential to resurge at Klotz Spring or be captured in the Kimbalton Mine. These areas will be reviewed if a release occurs.

Specific engineering and best management practices to be used in areas of steep slopes and slide prone areas.

DEQ Information Request No. 1: The plan should include notification to DEQ prior to initiating construction activity in areas with greater than 30 percent slopes. The notice should include at a minimum, the anticipated start date, location and duration of activity.

Mountain Valley Response No. 1: The Project has approximately 20.6 miles on slopes greater than 30% and at least 100 feet in length in Virginia. The mitigation measures are generally consistent with those recommended in the Interstate Natural Gas Association of America's (INGAA's) Mitigation of Land Movement in Steep and Rugged Terrain for Pipeline Projects published in May 2016, which presents best management practices for landslide mitigation in the Appalachian region.

Mountain Valley will conduct a pre-construction kickoff meeting with the contractors, inspectors, and VADEQ for each construction spread in Virginia. During this meeting, Mountain Valley will discuss the construction spread, including steep slopes, karst areas, and other sensitive resources, and the anticipated schedule for construction in all sensitive areas, including steep slopes and karst areas. All contractors and inspectors associated with construction will be required to complete Worker Environmental Awareness Program (WEAP) training. The WEAP training will be developed specifically for each construction spread and will clearly outline the procedures in the event of a slide, spill, or release entering an aquatic resource or other sensitive area. The pre-construction meeting will be held once for each construction spread.

DEQ Information Request No. 2: Include procedures and notifications to be implemented in the event a slide results in an impact to state waters.

Mountain Valley Response No. 2: The following is a general outline of the procedures and notification protocol in the event a slide results in an impact to state waters:

- The Environmental Inspector (EI) will immediately notify the Project's Environmental Coordinator and Construction Manager.
- The Project's Environmental Coordinator shall review the information to determine compliance with existing permits and notify the appropriate state and/or federal agencies as necessary within any applicable reporting deadlines.
- The EI shall provide the location of the slide (lat/long, Milepost and station) and name of stream or sensitive resource.
- The EI shall provide photographs of the slide and impacted stream or sensitive resource.
- The EI shall provide a description of the clean-up/restoration procedures to be implemented including measures to restore the impacted resource and measures being implemented to avoid future slides or slips.
- The Project's Environmental Coordinator and Construction Manager shall approve the clean-up/restoration procedures before the work begins.
- Once the work is completed, the EI shall provide photographs of the restored area.
- The information will be included in the weekly inspection report which will be provided to the FERC and DEQ.

Water Quality Monitoring Plan

DEQ Information Request No. 1: There appears to be upland construction activity near MP 204.3 at Little Stony Creek, which is designated as a Class VI "Good" Wild Trout stream. Please confirm potential impacts.

Mountain Valley Response No. 1: There are two project activities in the vicinity of MP 204.3. Mountain Valley will use an existing road, Archer Trail, for temporary site access The crossing will utilize an existing bridge across Little Stony Creek and therefore no direct impacts are anticipated from the use of this road. Additionally, the pipeline right-of-way will cross Little Stony Creek near MP 204.3 as well, resulting in a temporary impact to the stream. That instream impact has been included in the Joint Permit Application (JPA) and will be addressed in the permit authorization requested from the U.S. Army Corps of Engineers (Corps).

As with all Wild Trout streams within 50 feet of the limits of disturbance, this location was considered for monitoring in the Upland Construction Water Quality Monitoring Plan (UCWQMP). It was not selected, however, because monitoring this location would not produce data representative of upland construction activities. The pipeline route crosses this stream at a nearly perpendicular angle consistent with the Corps Norfolk District's Regional Condition NWP 12 3.b.i to minimize direct impacts. To minimize indirect impacts from upland construction activities, the temporary construction right-of-way is reduced, from 125 feet to 75 feet in the approach to (for approximately 250 feet) and from (for approximately 75 feet) Little Stony Creek, to create a riparian buffer from other upland construction activities. Due to the perpendicular crossing angle and reduced right-of-way width, there is very little upland drainage from the pipeline to this stream. Because potential impacts from upland ground-disturbance are not appreciably measurable at this location, this location was not included in the proposed monitoring locations for the UCWQMP.

DEQ Information Request No. 2: There appears to be upland construction activity near MP 222 at Mill Creek and MP 241/242 at Upper Bottom Creek, both designated as Class VI "Good" Wild Trout streams. Please confirm potential impacts.

Mountain Valley Response No. 2: The primary activity with the potential to affect the unnamed tributary (UNT) to Mill Creek near MP 222 is the pipeline crossing, which occurs upstream and prior to the pipeline running parallel to the stream. There is very little drainage from the pipeline right-of-way to the UNT to Mill Creek near MP 222 due to its location on the topography and the perpendicular approaches to the stream. The adjacent access road is an existing road and no ground-disturbance impacts will occur along the road. Thus upland impacts are not appreciably measurable at this location. Only potential direct impacts from the stream crossing reasonably could be captured due to the upstream pipeline crossing. Similarly, the primary activity affecting Upper Bottom Creek in the vicinity of MP 241/242 is from the pipeline crossing which occurs upstream and prior to the pipeline running roughly parallel to the stream for a short distance. Because the specific purpose of the UCWQMP is to isolate and monitor potential impacts from upland construction activities, this site was not recommended for monitoring in this plan. See DEQ Information Request (May 19, 2017) (requesting that MVP develop a plan "detailing measures to monitor potential impacts from upland ground-disturbing activities"). The other sites that were selected for monitoring will produce representative data on the effectiveness of MVP's water protection measures for upland construction.

DEQ Information Request No. 3: If confirmed that upland construction will occur within 50 feet of these Class VI streams (identified above), the agency requests that the MVP monitoring plan include at least one monitoring station to evaluate impacts to Class VI trout waters.

Mountain Valley Response No. 3: As stated in the response to comments 1 and 2 within this section, monitoring of *upland impacts* in the vicinity of these Class VI streams is not reasonably possible due to the pipeline configuration and the location of the stream crossings. Mountain Valley is proposing monitoring four other trout streams in an effort to ensure that impacts to trout populations are not occurring as a result of pipeline construction. Information on these four trout streams is included in the UCWQMP.

DEQ Information Request No. 4: The station(s) cited to evaluate impacts to wild trout streams should include a method to check wild trout populations before, during and after construction.

Mountain Valley Response No. 4: The proposed chemical parameters selected for monitoring (i.e., temperature, dissolved oxygen, specific conductance, pH, and turbidity) are important water quality indicators for all aquatic species, including the sensitive species potentially found at the monitoring locations. Monitoring these chemical parameters, as supplemented by the physical and benthic monitoring, will allow potential water quality-related impacts to aquatic life in the subject streams to be appropriately characterized. Furthermore, it is important to recognize that fish studies conducted over the short duration of Project construction will not provide statistically valid or otherwise useful information about existing fish populations or potential impacts on these populations. Fish are a highly mobile species and their presence within a specific section of stream is highly variable depending on time of year, stream temperature fluctuations, flow rates, storm events, and other environmental factors. As noted in EPA document 600-R-06-127 (Concepts and Approaches for the Bioassessment of Non-Wadeable Streams and Rivers[4]), fish are good indicators of long-term effects (this monitoring program is focused on short-term effects) and due to the seasonal mobility of fish they are typically less indicative of localized disturbances. Thus, findings from one sampling event may differ significantly from future events, regardless of pipeline activities.

DEQ Information Request No. 5: 6 of 9 sites included in Table 2 include threatened or endangered species. The monitoring plan should include a method to check threatened or endangered species populations before, during and after construction.

Mountain Valley Response No. 5: Revisions to the UCWQMP are not reasonably necessary to evaluate potential impacts on the identified sensitive species for several reasons. The Endangered/threatened species waters (ETS) of concern at 5 of the 6 noted locations are species of fish (Roanoke logperch, candy darter, and orangefin madtom). The ETS of concern for 2 of the 6 noted locations are species of freshwater mussel (green floater and James spineymussel). Note that there is overlap between one of the streams. MVP has engaged in consultation with the relevant federal and state agencies (U.S. Fish and Wildlife Service, Virginia Department of Conservation and Recreation, and Virginia Department of Game and Inland Fisheries) for each of these species. MVP will adhere to time-of-year restrictions and other requirements developed in consultation with these expert agencies to avoid adverse impacts on these species. See DEIS § 4.7.1.1.

The proposed chemical parameters selected for monitoring (i.e., temperature, dissolved oxygen, specific conductance, pH, and turbidity) are important water quality indicators for all aquatic species, including the sensitive species potentially found at the monitoring locations. Monitoring these chemical parameters, as supplemented by the physical and benthic monitoring, will allow potential water quality-related impacts to aquatic life in the subject streams to be appropriately characterized. Furthermore, it is important to recognize that fish studies conducted over the short duration of Project construction will not provide statistically valid or otherwise useful information about existing fish populations or potential impacts on these populations. As previously stated, fish are highly mobile species and their presence within a specific section of stream is highly variable depending on time of year, stream temperature fluctuations, and other environmental factors. Thus, findings from one sampling event may differ significantly from future events, regardless of pipeline activities.

DEQ Information Request No. 6: Lat/long coordinates of the above, adjacent and below sites along each

[4] Flotemersch, J.E., J.B.Stribling, and M.J. Paul. 2006. Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers. EPA 600-R-06-127. U.S. Environmental Protection Agency, Cincinnati, OH. Available at: https://www3.epa.gov/region1/npdes/merrimackstation/pdfs/ar/AR-1157.pdf; accessed June 19, 2017.

selected reach should be provided as soon as possible. Sub-meter accuracy, as indicated in the monitoring plan, is not immediately necessary but an estimate of the distances from monitoring sites to activity areas would be beneficial.

Mountain Valley Response No. 6: Approximate Lat/long coordinates of the proposed monitoring station locations are provided in a table on each of the maps in the revised UCWQMP, subject to field adjustment and final survey location. A scale bar is also provided so that distances from monitoring sites to the activity areas can be measured. Additionally, based on further review of the monitoring station locations, the monitoring location for Site 6D has been relocated near the I-81 rest area, and the monitoring location for Site 7D has been relocated near the Mill Creek Road crossing as noted in the revised UCWQMP. The revised UCWQMP is included as Appendix 2.

DEQ Information Request No. 7: The proposed monitoring frequency for chemical parameters is far less than normally relied on to make water quality determinations. One reading for DO, pH, conductivity, and turbidity done before, during, and after construction is insufficient to determine if there is an actual water quality impairment. To make such determinations, the agency prefers continuous monitoring of these parameters for a duration of one month to occur before, during, and after construction. However, DEQ requests that, at a minimum, three grab samples be collected at each site before, during, and after construction (total of nine samples per site). The grab samples should be collected at least one week apart.

Mountain Valley Response No. 7: As requested, three sample events at each monitoring location will be conducted at each location before, during, and after construction (i.e., three pre-construction events, three active construction events, and three post-construction events). Sample events will be conducted a minimum of 1 week apart. The UCWQMP has been revised to reflect this frequency. Continuous monitoring is not proposed due to risk of vandalism of the equipment and the potential to lose monitoring equipment during flood events. Moreover, Mountain Valley is confident that the revised sampling frequency is sufficient in most circumstances to determine if upland construction activities have had a potential impact on water quality.

DEQ Information Request No. 8: There is no detail on how far apart benthic monitoring will occur during the project. For benthic parameters, changes to the community will happen over time. DEQ recommends that benthic sampling be conducted one month before, immediately after, and at least a month after actual construction.

Mountain Valley Response No. 8: Benthic sampling will occur once before, during, and after construction, provided that the sampling can occur within the spring or fall index period (March 1 through May 31 and September 1 through November 30). The post-construction benthic sampling will occur at least a month after construction completion and ground stabilization, provided that sampling can occur within the spring or fall index period. Otherwise sampling will take place in the first available index period. Section 5 of the UCWQMP has been revised accordingly.

DEQ Information Request No. 9: The document specifies that duplicate chemical/physical sampling via two staff collecting samples at the same time and location will occur. Does this mean every sample will be collected in this manner? If not, please specify the frequency of duplicate sampling.

Mountain Valley Response No. 9: Yes, duplicate sampling will be conducted for each sample at the stated frequency of 3 samples before, during, and after construction.

DEQ Information Request No. 10: DEQ requests that the agency be notified to enable observation of at least one benthic sampling event to document performance of the sampling teams. In addition, DEQ requests that the contracted laboratory provide two randomly selected benthic samples, as selected by DEQ, including all identified organisms and material from which they were sorted, in order to verify identification accuracy and sorting efficiency. This is a routine procedure when the agency evaluates submitted data.

Mountain Valley Response No. 10: A schedule of sampling events will be provided to DEQ at least one week prior to each sampling period. A sampling of random benthic specimens from the sampling locations will also be provided by the processing laboratory. Section 7 of the UCWQMP has been revised to reflect this change.

DEQ Information Request No. 11: DEQ staff can provide guidance on adherence to Standard Operating Procedures for all aspects of the proposed monitoring, as requested by the contractors.

Mountain Valley Response No. 11: Mountain Valley will inform project contractors of the opportunity to seek monitoring guidance and clarification from the agency if needed.

DEQ Information Request No. 12: DEQ requests that all raw data be provided in electronic form.

Mountain Valley Response No. 12: Data will be provided in electronic form (PDF and Excel) as noted in Section 8 of the revised UCWQMP.

Karst Mitigation Plan

DEQ Information Request No. 1: All field surveys for identification of karst features and associated documentation shall be completed and submitted to DEQ at least 14 days prior to initiation of land disturbance activities in those areas.

Mountain Valley Response No. 1: Field verification of MVP's desktop analysis of potential karst features within 150 feet of the approved alignment is nearly complete. The only remaining areas to survey in the field are parcels for which MVP's surveyors have been denied access by the landowner. MVP is actively pursuing its rights under state law to obtain access to these sites to conduct necessary environmental surveys, including for karst features. If any parcels remain unsurveyed by September 2017, MVP will obtain additional rights under federal law to access properties when the Federal Energy Regulatory Commission (FERC) issues a certificate for the Project. Mountain Valley will complete karst surveys on all parcels within 150 feet of the approved final alignment and will update its Karst Hazards Assessment (KHA) document accordingly as soon as reasonably possible. Mountain Valley will provide a copy of that document to the DEQ at that time. Mountain Valley expects this process to be complete well in advance of land disturbance in those areas, but the actual completion may be dependent on land access issues that are beyond its control.

Please note that karst protection efforts will be on-going during all phases of pipeline construction through final land reclamation, and Mountain Valley has committed to keeping the Commonwealth, through the Virginia Department of Conservation and Recreation (DCR) Karst Protection Coordinator, apprised of karst feature assessments, avoidance, and mitigation if necessary.

DEQ Information Request No. 2: The plan should include notification to DEQ prior to initiating construction activity in areas with karst terrain. The notice should include at a minimum, the anticipated start date, location and duration of activity

Mountain Valley Response No. 2: Mountain Valley will conduct a pre-construction kickoff meeting with the contractors, inspectors, and VADEQ for each construction spread in Virginia. During this meeting, Mountain Valley will discuss the construction spread, including steep slopes , karst areas, and other sensitive resources, and the anticipated schedule for construction in all sensitive areas, including steep slopes and karst areas. All contractors and inspectors associated with construction will be required to complete Worker Environmental Awareness Program (WEAP) training. The WEAP training will be developed specifically for each construction spread and will clearly outline the procedures in the event of a slide, spill, or release entering an aquatic resource or other sensitive area. The pre-construction meeting will be held once for each construction spread

More specifically, Mountain Valley will notify the DEQ prior to, and after completion of, construction within areas of karst terrain (see Karst Hazard Assessment plan for identification of karst areas relative to the proposed alignment and workspaces). Mountain Valley will provide an anticipated start date, range of mileposts in karst terrain in the specific "spread" and an estimate of construction duration. There are many factors that can affect the construction schedule and the dates and duration of construction will be estimated based on the best available information. However, actual dates or duration of construction may deviate from the schedule.

DEQ Information Request No. 3: Provide clarification regarding field investigation procedures occurring between tree clearing and initiation of construction activity.

Mountain Valley Response No. 3: Field investigation for karst features will occur concurrently with tree clearing, but not in the period between tree clearing and the initiation of construction activity. As discussed in the Karst Mitigation Plan (KMP), Mountain Valley will deploy a Karst Specialist Team (KST), as part of the construction inspectors team, during all phases of construction and land reclamation that takes place in karst terrain. This will include the KST being on-site during initial tree clearing and grubbing. The purpose for this is to identify any karst features that may have been obscured by vegetation during the initial field verification work for the Karst Hazards Assessment (KHA), as well as to observe previously identified karst features during land clearing, and to ensure that the features are avoided or mitigated/stabilized. The Mountain Valley KMP describes Mountain Valley's inspection procedures for new karst features, as well as mitigation and stabilization measures to be taken if a karst feature cannot be avoided. The KMP also specifies that the Department of Conservation and Recreation - Karst Protection, will be notified if any new karst features are discovered, and notified if any karst feature mitigation/stabilization measures are undertaken. Once initial land clearing is completed, and the KST has inspected the limit of disturbance (LOD), no further field investigation by the KST is anticipated (unless additional field investigation is required for a newly observed karst feature) until construction is resumed in the specific area of karst terrain. These inspection activities will be documented in construction inspection field logs, which will be made available to DEQ upon request during construction.

DEQ Information Request No. 4: To further evaluate flow paths for significant karst features in the vicinity of the project, MVP shall develop a Karst Dye Tracing Plan to be submitted and approved prior to initiation of land disturbance activities in karst terrain. See Attachment B.

Mountain Valley Response No. 4: As discussed in the June 8, 2017, Mountain Valley is preparing a Supplemental Karst Evaluation Plan in accordance with the areas of concern identified by DCR (i.e., Attachment B of the DEQ's June 15, 2017 Data Request letter). The plan will be provided to DEQ before July 5, 2017, as agreed in the June 8, 2017 meeting.

Supplements to Mountain Valley's June 1, 2017 Information Request Response

DEQ Information Request No. 11A: Identify known karst features within areas of land disturbance activities for construction of a pipeline and related access roads and appurtenances**.**

Supplement to Mountain Valley Response No. 11A: As a result of further consultation with DEQ, Mountain Valley's final approved S&S now includes a provision specifying that the locations of all known karst features be included on the site-specific ESC Plans that will be used in the field.[5] S&S § 5.3.5. This measure will better enable DEQ to review the proposed erosion and sediment controls and stormwater BMPs in karst areas to ensure they are protective of karst features along the Project route. Likewise, this will aid EIs and construction crews in ensuring that karst features are protected in the field during construction.

DEQ Information Request No. 12: Description of onsite environmental monitoring and inspection measures to be implemented during construction.

Supplement to Mountain Valley Response No. 12: In its June 1, 2017 response, MVP identified inspection frequencies for temporary erosion and sediment controls and stormwater BMPs (p. 28), which were drawn from the then-current draft S&S. After further consultation with DEQ, the minimum inspection frequency in the final approved S&S has been revised to require *more frequent* inspections on the following schedules:

- **In non-TMDL watersheds**:
  - At least once every five business days; or
  - At least once every 10 business days and no later than 48 hours following a measurable storm event (or on the next business day if the storm event occurs when there are more than 48 hours between business days).

- **In TMDL watersheds**:
  - At least once every four business days; or
  - At least once every five business days and no later than 48 hours following a measurable storm event (or on the next business day if the storm event occurs when there are more than 48 hours between business days).

Mountain Valley further notes that these inspection frequencies are stated as *minimum* requirements. Actual inspection schedules, as determined by the EI, are likely to be more frequent.

* * *

Mountain Valley looks forward to continuing to work with DEQ moving forward. Please feel free to contact me if you have questions or need any additional information. Thank you for your time and consideration.

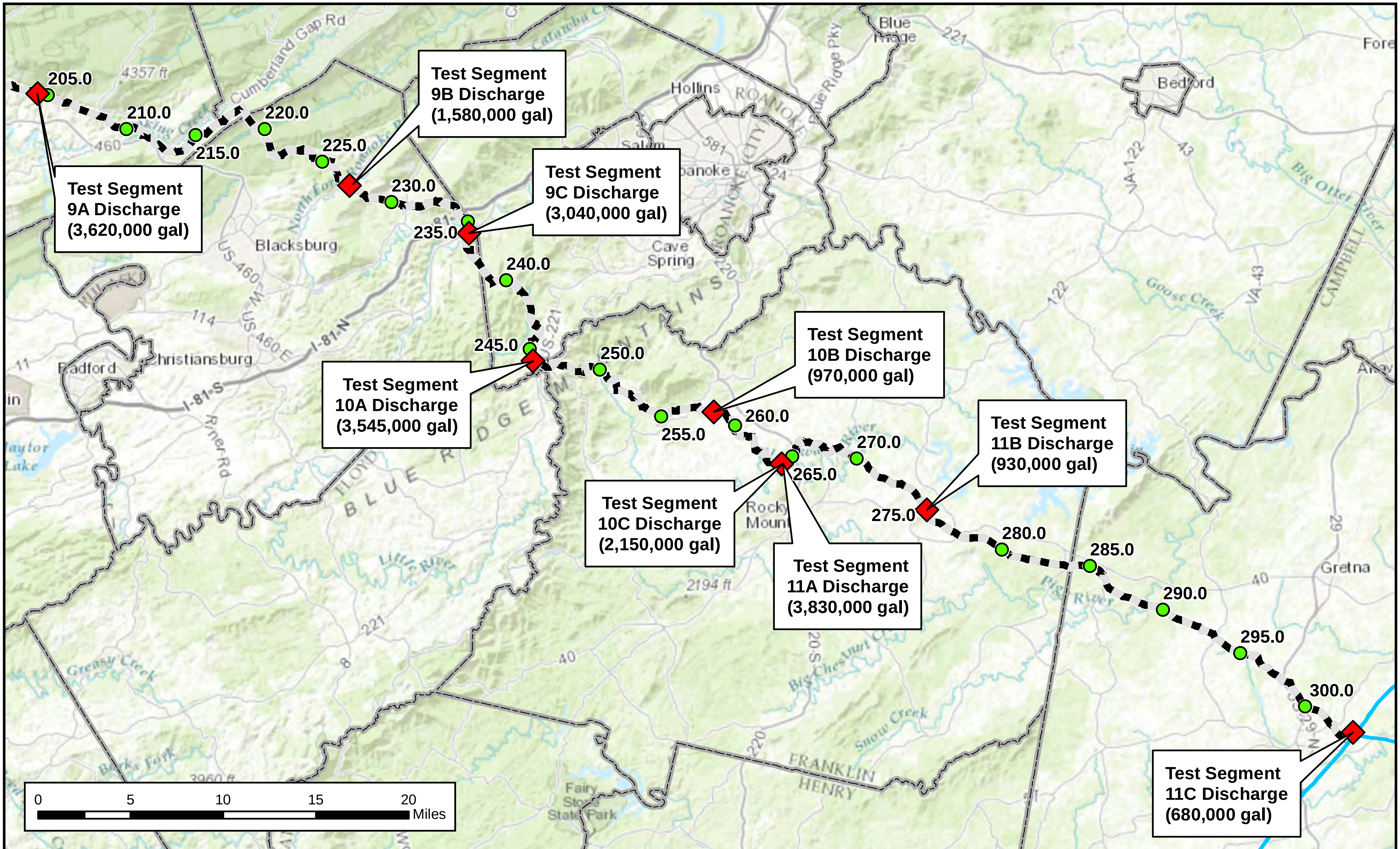
Sincerely,

John Centofanti
Corporate Director Environmental Affairs
(412) 395-3305
JCentofanti@eqt.com

[5] The S&S also have been revised to require that other environmentally sensitive areas be identified on the ESC Plans, including steep slopes, erodible soils, and water supply sources. S&S §§ 5.3.1, 5.3.2, 5.3.8.

Appendix List

Appendix 1:
Hydrostatic Discharge Mapping



![Mountain Valley Pipeline logo]

Mountain Valley
PIPELINE

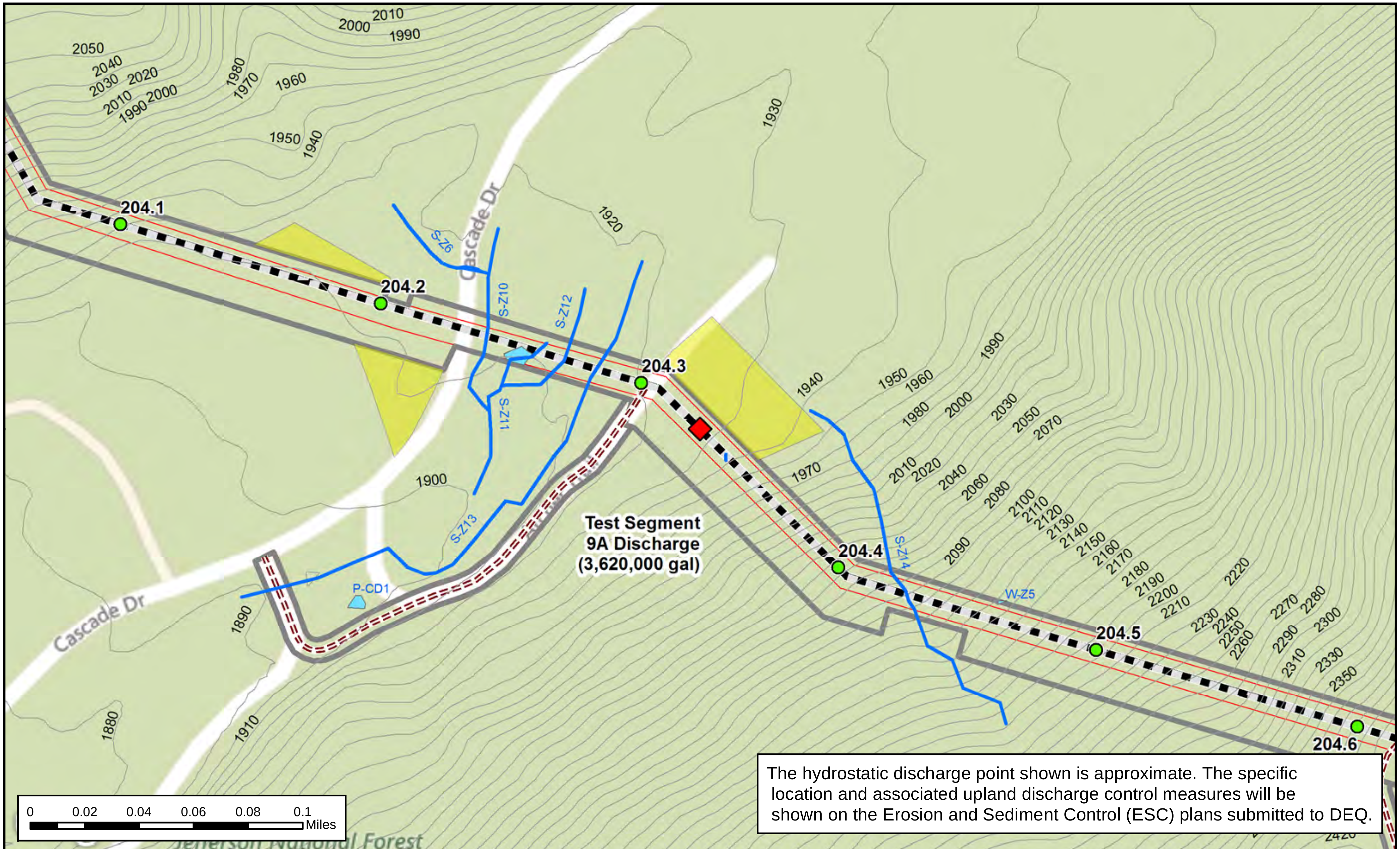
MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST
OVERVIEW

Sheet 1 of 10

6/21/2017

LEGEND

- VA Hydrostatic Test Discharge
- Proposed Route
- Transco



The hydrostatic discharge point shown is approximate. The specific location and associated upland discharge control measures will be shown on the Erosion and Sediment Control (ESC) plans submitted to DEQ.

Mountain Valley PIPELINE

MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST
Test Segment 9A Discharge (3,620,000 gal)

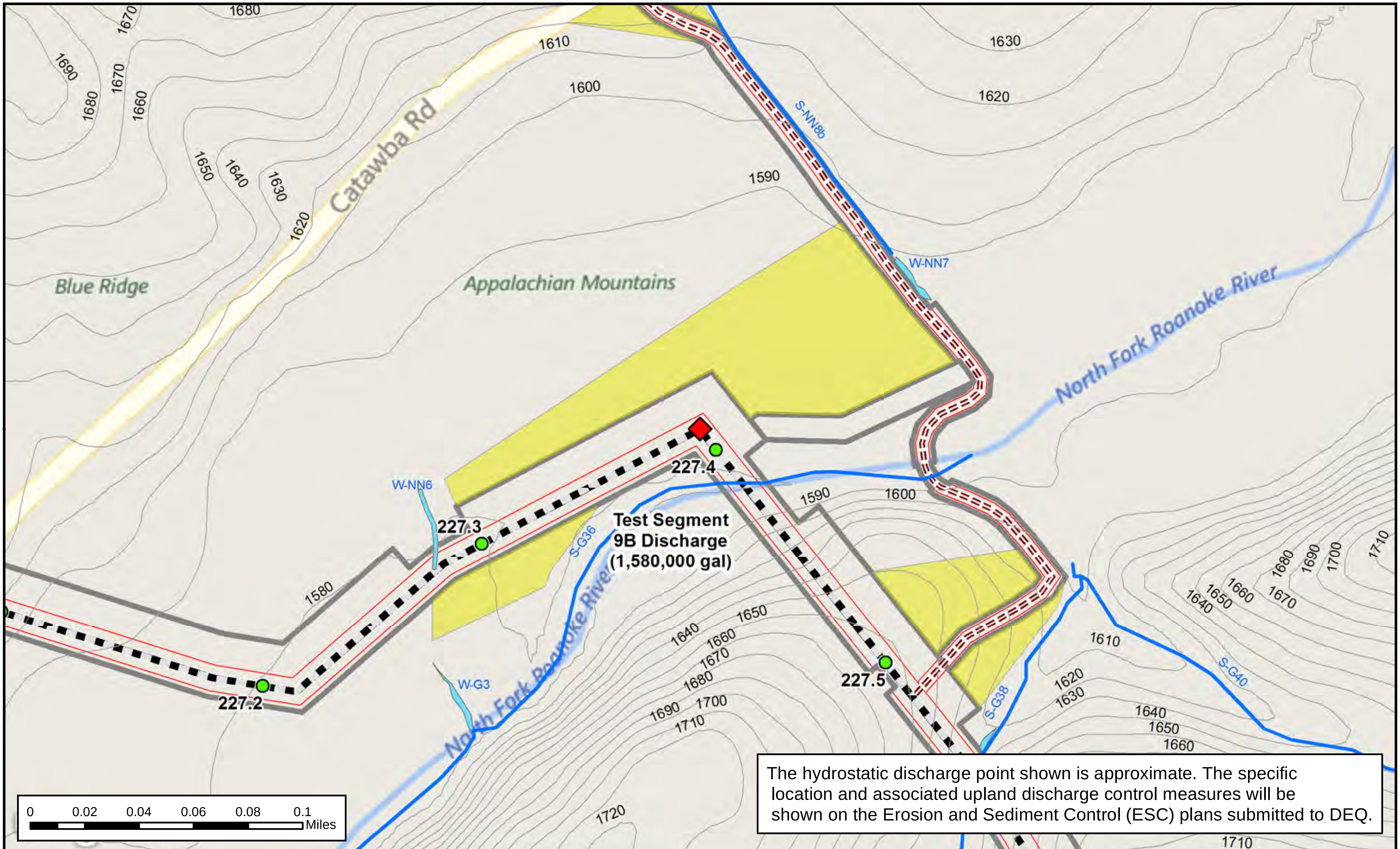
Sheet 2 of 10

6/21/2017

1:3,000

LEGEND

- **VA Hydrostatic Test Discharge**
- **Proposed Route**
- **Proposed Route Access Road**
- **Proposed Route TWS**
- **Proposed Route PE**
- **Proposed Route ATWS**



Mountain Valley PIPELINE

MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST
Test Segment 9B Discharge (1,580,000 gal)

Sheet 3 of 10

6/21/2017

1:3,000

LEGEND

- **VA Hydrostatic Test Discharge**
- **Proposed Route**
- **Proposed Route Access Road**
- **Proposed Route TWS**
- **Proposed Route PE**
- **Proposed Route ATWS**

Mountain Valley PIPELINE

MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST
Test Segment 9C Discharge (3,040,000 gal)

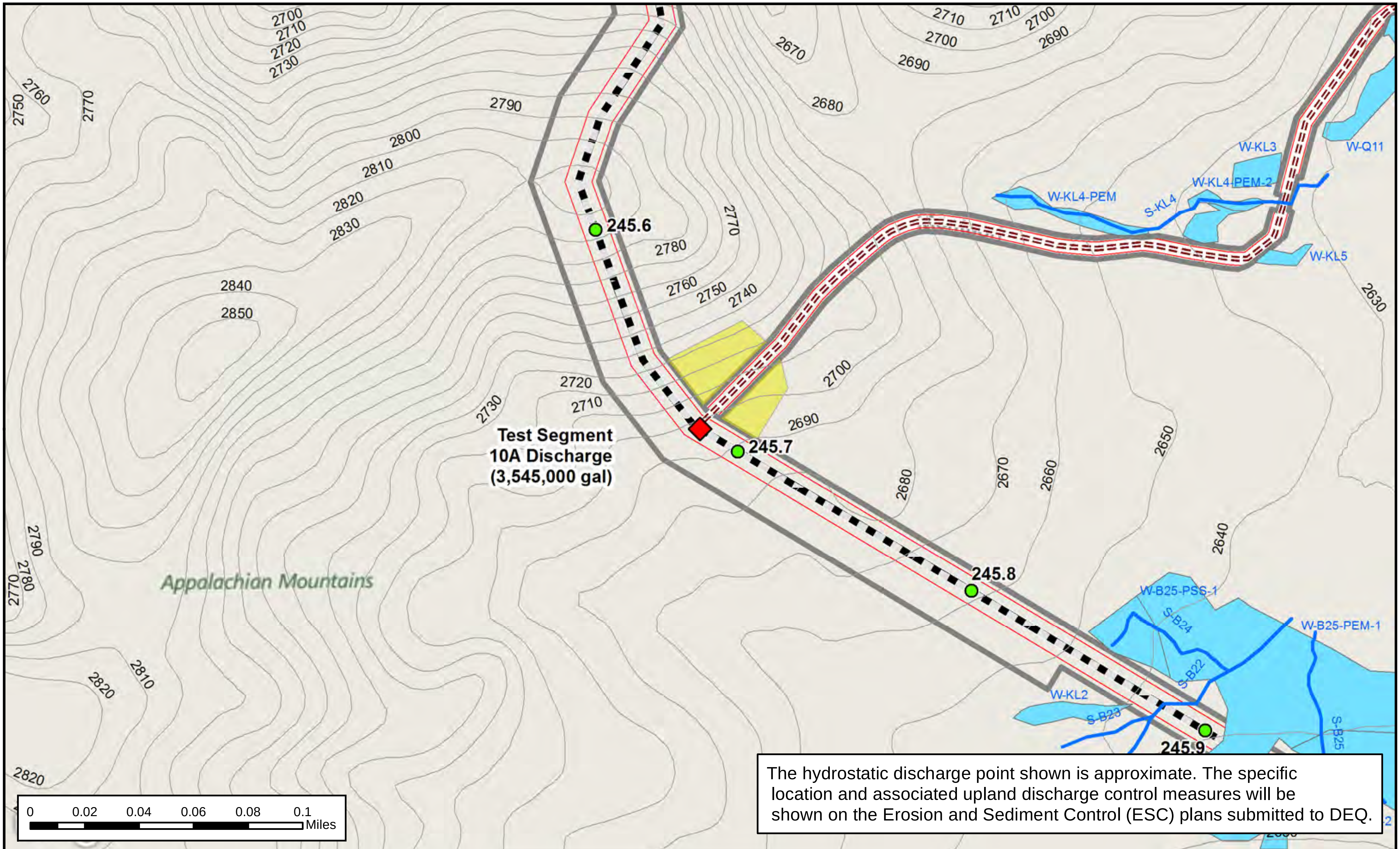
Sheet 4 of 10

6/21/2017

1:3,000

LEGEND

- VA Hydrostatic Test Discharge
- Proposed Route
- Proposed Route Access Road
- Proposed Route TWS
- Proposed Route PE
- Proposed Route ATWS



Mountain Valley PIPELINE

MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST
Test Segment 10A Discharge (3,545,000 gal)

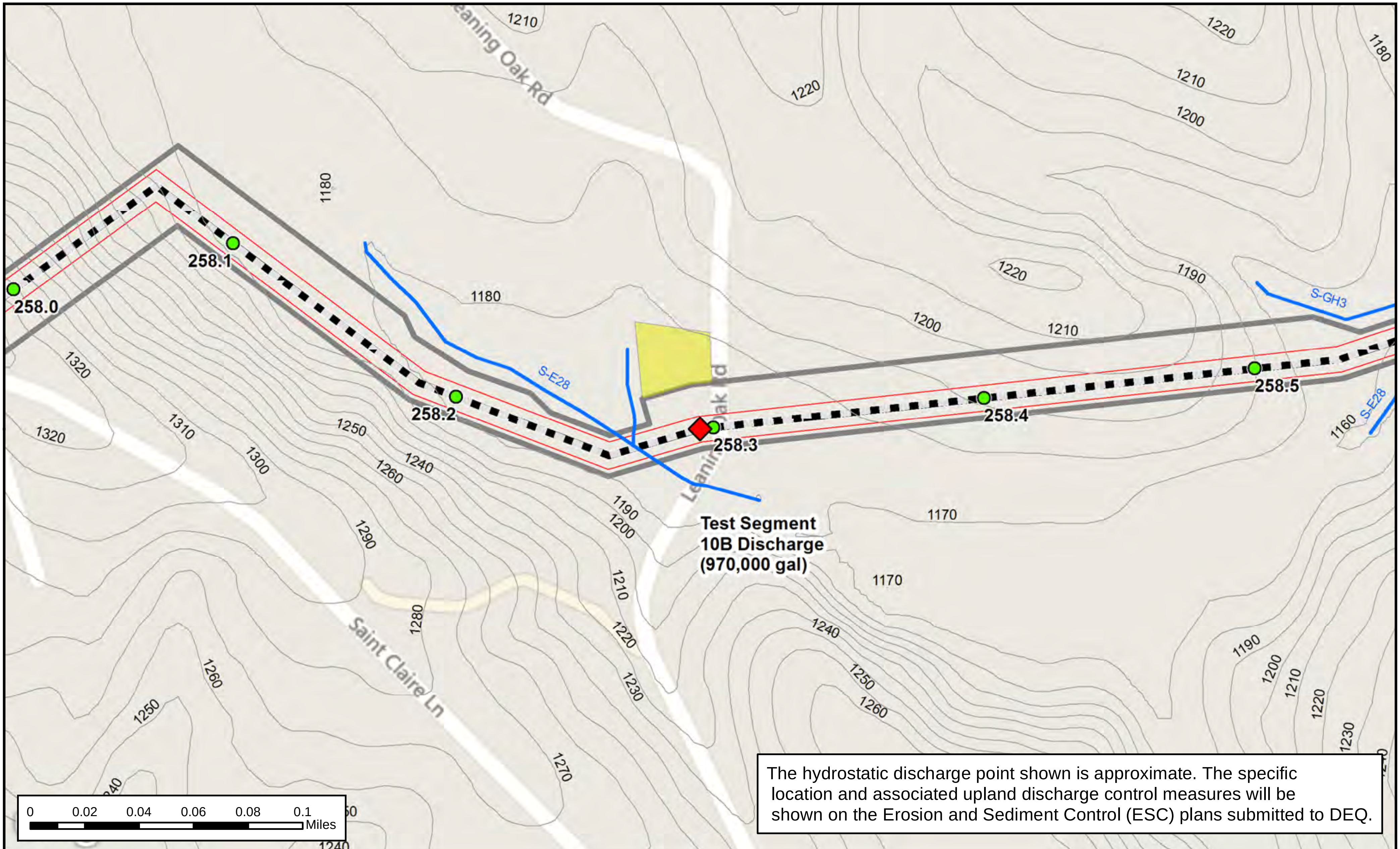
Sheet 5 of 10

1:3,000

6/21/2017

LEGEND

- **VA Hydrostatic Test Discharge**
- **Proposed Route**
- **Proposed Route Access Road**
- **Proposed Route TWS**
- **Proposed Route PE**
- **Proposed Route ATWS**



MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST

Test Segment 10B Discharge (970,000 gal)

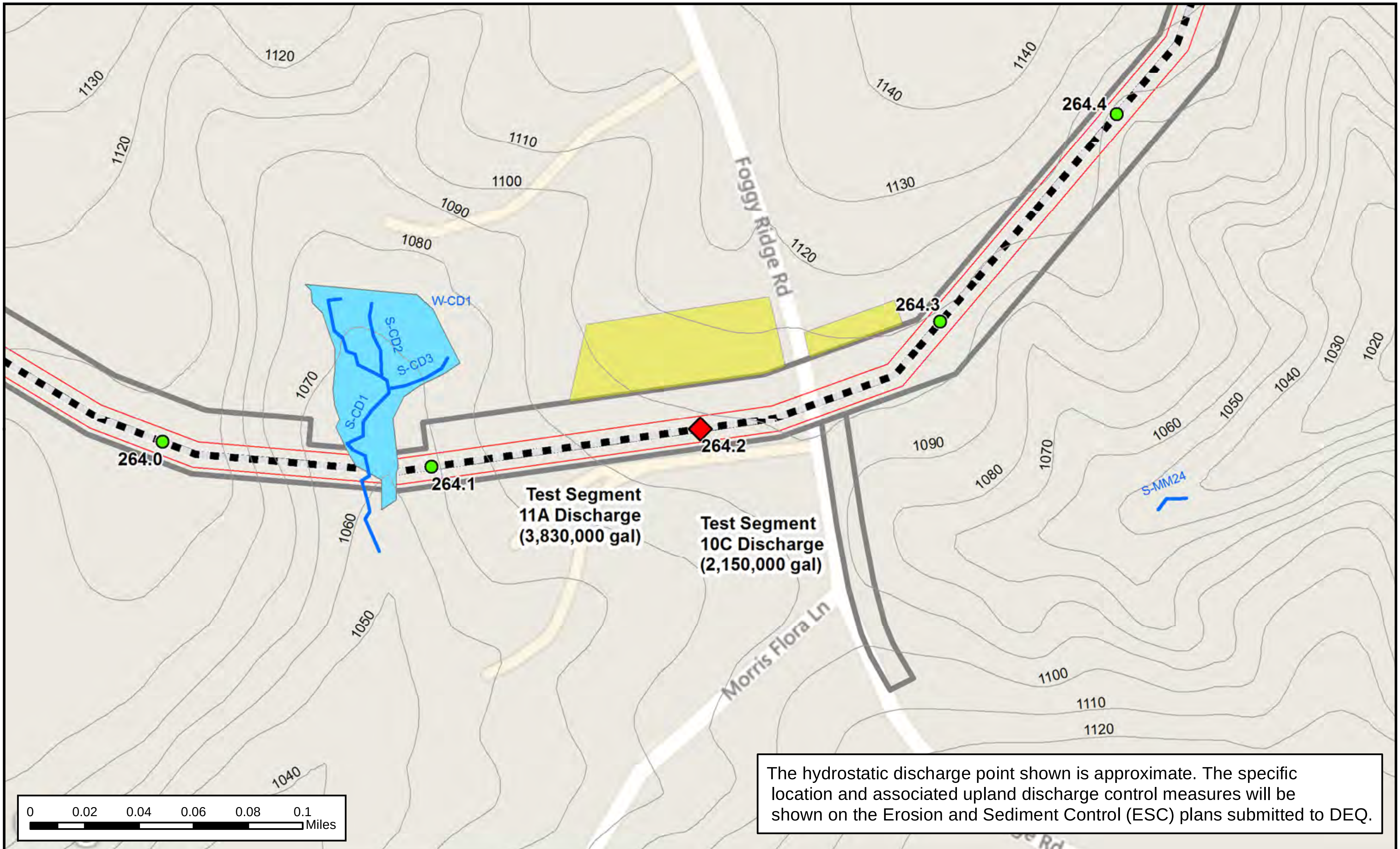
Sheet 6 of 10

6/21/2017

1:3,000

LEGEND

- VA Hydrostatic Test Discharge
- Proposed Route
- Proposed Route Access Road
- Proposed Route TWS
- Proposed Route PE
- Proposed Route ATWS



Mountain Valley PIPELINE

MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST
Test Segment 10C Discharge (2,150,000 gal)

Sheet 7 of 10

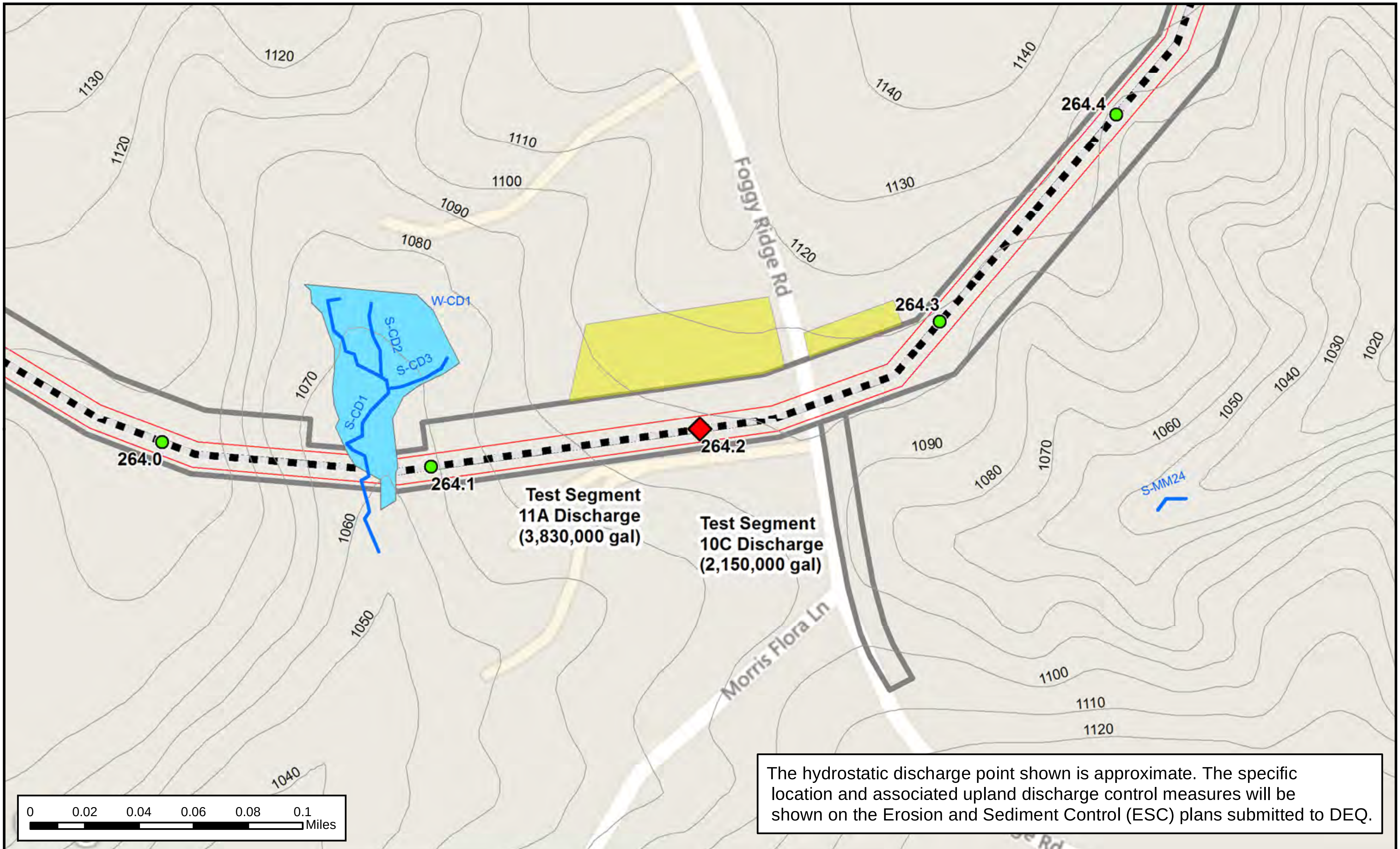
6/21/2017

1:3,000

N W E S

LEGEND

- **VA Hydrostatic Test Discharge**
- **Proposed Route**
- **Proposed Route Access Road**
- **Proposed Route TWS**
- **Proposed Route PE**
- **Proposed Route ATWS**



The hydrostatic discharge point shown is approximate. The specific location and associated upland discharge control measures will be shown on the Erosion and Sediment Control (ESC) plans submitted to DEQ.

Mountain Valley PIPELINE

MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST
Test Segment 11A Discharge (3,830,000 gal)

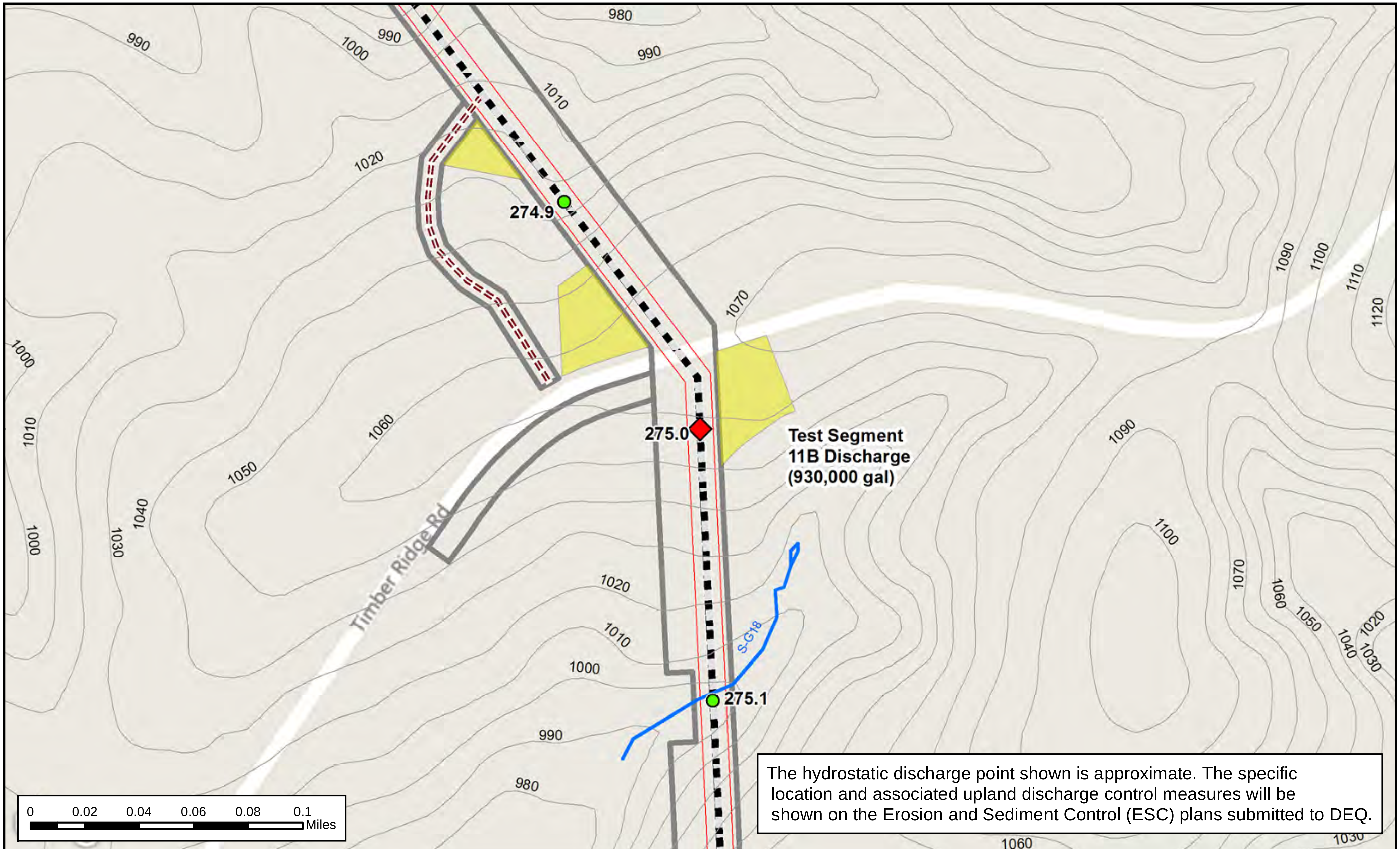
Sheet 8 of 10

6/21/2017

1:3,000

LEGEND

- **VA Hydrostatic Test Discharge**
- **Proposed Route**
- **Proposed Route Access Road**
- **Proposed Route TWS**
- **Proposed Route PE**
- **Proposed Route ATWS**



Mountain Valley PIPELINE

MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST

Test Segment 11B Discharge (930,000 gal)

Sheet 9 of 10

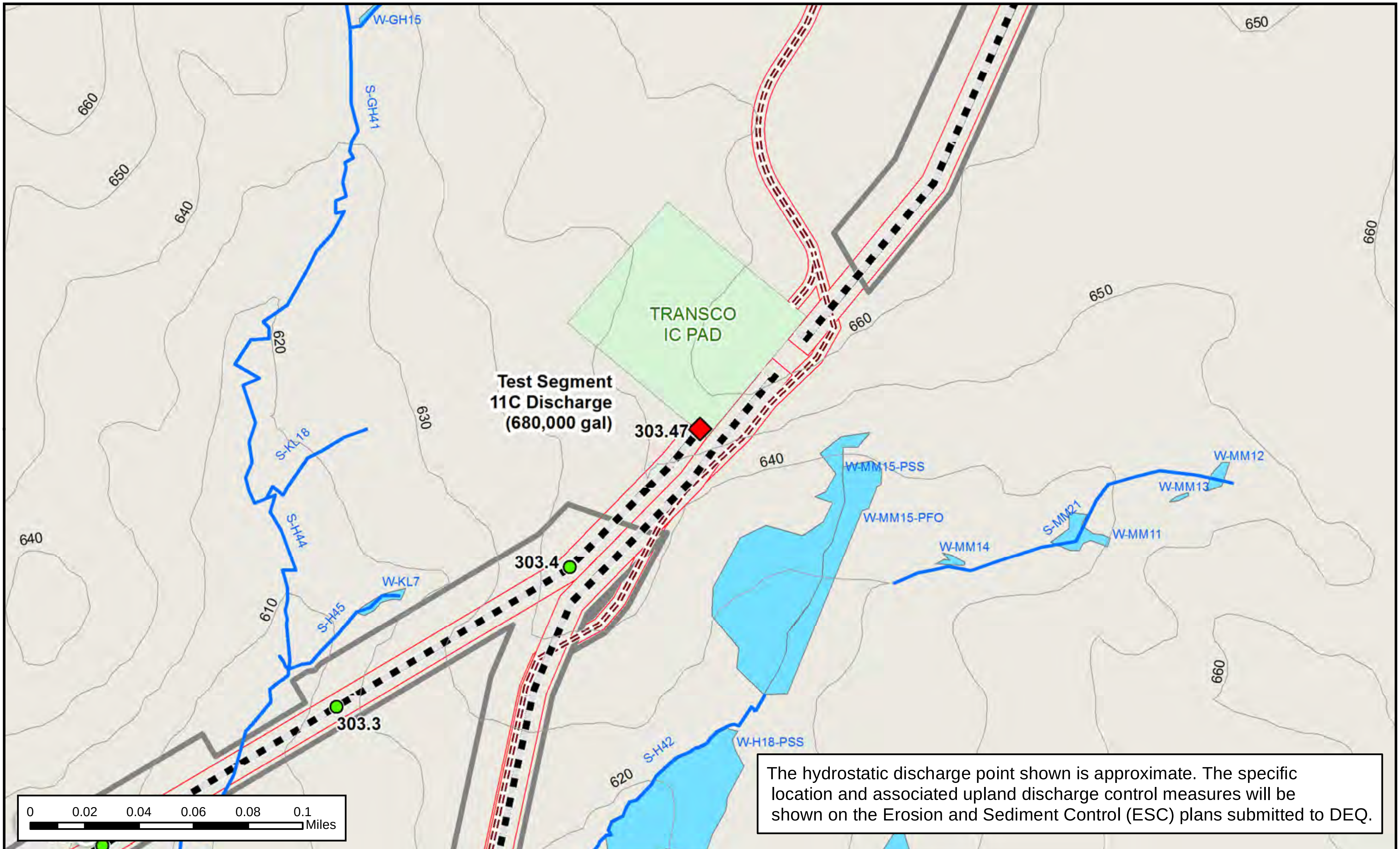
6/21/2017

1:3,000

N W E S

LEGEND

- **VA Hydrostatic Test Discharge**
- **Proposed Route**
- **Proposed Route Access Road**
- **Proposed Route TWS**
- **Proposed Route PE**
- **Proposed Route ATWS**



The hydrostatic discharge point shown is approximate. The specific location and associated upland discharge control measures will be shown on the Erosion and Sediment Control (ESC) plans submitted to DEQ.

Mountain Valley PIPELINE

MOUNTAIN VALLEY PIPELINE
VA HYDROSTATIC TEST
Test Segment 11C Discharge (680,000 gal)

Sheet 10 of 10

1:3,000

6/21/2017

LEGEND

- VA Hydrostatic Test Discharge
- Proposed Route
- Proposed Route Access Road
- Proposed Route TWS
- Proposed Route PE
- Proposed Route ATWS

Appendix 2:
Upland Construction Water Quality Monitoring Plan
(May 31, 2017, Revised June 19, 2017)

Upland Construction Water Quality Monitoring Plan

May 31, 2017
Revised June 19, 2017

Table of Contents

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

ATWS	Additional Temporary Work Space
DEQ	Virginia Department of Environmental Quality
JPA	Joint Permit Application
MVP	Mountain Valley Pipeline
QA/QC	Quality Assurance and Quality Control
QAAP	Quality Assurance Project Plan
TMDL	Total Maximum Daily Load
UCWQMP	Upland Construction Water Quality Monitoring Plan

Mountain Valley PIPELINE

Upland Construction Water Quality Monitoring Plan

1.0 Introduction

This Upland Construction Water Quality Monitoring Plan (UCWQMP) has been prepared at the Virginia Department of Environmental Quality's (DEQ) request to monitor for potential water quality impacts from the Mountain Valley Pipeline's proposed upland ground-disturbing activities. This plan is intended to generate representative monitoring data that will provide assurance that the approved erosion and sediment controls and other similar water quality control measures are effective. Monitoring locations have been identified to encompass different upland construction activities (e.g., pipeline and access road land disturbances) and different types of sensitive streams in the vicinity of the Project. The chemical and biological monitoring parameters have been selected to address impacts that generally could be associated with ground-disturbing activities.

1.1 Stream Criteria Considered for Monitoring

Pursuant to the DEQ "Request for Information for Developing and Evaluating Additional Conditions for Section 401 Water Quality Certification for Interstate Natural Gas Infrastructure Project," dated May 19, 2017, streams with the following characteristics were reviewed and considered for water quality monitoring:

1. Wild/stocked trout streams;
2. Endangered/threatened species (ETS) waters;
3. Designated public water supply streams;
4. TMDL watersheds with established TMDL's;
5. Tier 3 streams;
6. Areas near acidic soils.

There are no Tier 3 streams within proximity to the Project limits of disturbance (see Draft Environmental Impact Statement 4-90); thus, the final list of stream types considered are listed in Table 1:

Table 1: Stream Criteria
Wild/stocked Trout Streams (Trout)
Endangered/threatened species waters (ETS)
Within 5 miles upstream of a Public Water Supply[1] (PWS)
TMDL watersheds (TMDL)
Areas near acidic soils[2] (Acid)

[1] http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityAssessments/2014305(b)303(d)IntegratedReport.aspx. Accessed May 2017

[2] Areas near acidic soils were defined as those where the drainage area of the pipeline right of way intersects acid forming soils and flows into a stream.

2.0 Potential Streams to be Monitored

Utilizing the criteria from Table 1 above and cross-referencing with the National Hydrological Dataset, Preliminary Draft Joint Permit Application (JPA) dated May 16, 2017, the Virginia DEQ list of Draft and Final TMDL Implementation Plans[3], and the Acid Forming Materials Mitigation Plan (prepared by Draper Aden Associates, dated May 2017), Mountain Valley Pipeline (MVP) identified streams for potential monitoring.

To meet the DEQ criteria for this UCWQMP, the limits of upland ground-disturbing activities were then assessed to locate Project areas that are in the vicinity of and upgradient from streams that meet the criteria for this analysis. To isolate potential impacts from upland activities, this plan does not include sampling locations that are immediately downstream of Project stream crossings.[4]

3.0 Recommended Monitoring Locations

The following selection criteria was developed to determine the high priority streams to be recommended for monitoring (Table 2):

- Only perennial streams (based on the flow regime provided in the JPA or the National Hydrological Dataset) were considered to ensure that flow would be present to collect data for the necessary monitoring parameters during sampling periods
- A minimum of one stream for each type of criteria was selected;
- Streams that met more than one of the criteria (e.g., were both a Trout Stream and an ETS water) were preferred;
- Streams which were listed only due to a TMDL for bacteria were not considered due to the lack of a relevant monitoring parameter (i.e., fecal coliform was not requested as a monitoring parameter).

Table 2: Recommended Monitoring Locations

Stream ID	NHD Stream Name	County	Criteria Met	Project Activity
1	Clendenin Creek	Giles	PWS Intake, Acid	Access Road
2	Sinking Creek	Giles	Trout	Access Road
3	Sinking Creek	Giles	Trout, ETS	Pipeline, Access Road, ATWS[5]
4	Sinking Creek	Giles	Trout, ETS	Pipeline, Access Road, ATWS
5	Craig Creek	Montgomery	ETS, TMDL (Sediment), Acid, Trout	Pipeline, Access Road, ATWS

[3] Available at: http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/TMDL/TMDLImplementation/TMDLImplementationPlans.aspx Accessed May 19, 2017

[4] Potential impacts associated with stream and wetland crossings are addressed separately in MVP's draft Joint Permit Application, which will serve as preconstruction notification for coverage under Nationwide Permit 12.

[5] Additional Temporary Workspace (ATWS)

6	North Fork Roanoke	Montgomery	ETS, PWS, TMDL (Bacteria)	Pipeline, Access Road
7	Mill Creek	Roanoke	Trout, TMDL (Bacteria and Sediment)	Pipeline, Access Road, ATWS
8	Little Creek	Franklin	ETS, TMDL (Bacteria)	Pipeline, Access Road, ATWS
9	Blackwater	Franklin	ETS, PWS, TMDL (Bacteria)	Pipeline, Access Road, ATWS

Three sampling points are recommended for each sampling location for Chemical and Physical Parameters. One sample point will be upstream of the adjacent construction area, one sample point will be immediately adjacent to the construction area, and one sample point will be downstream of the adjacent construction area. Biological monitoring shall only be conducted upstream and downstream of the adjacent construction area. The purpose of the sampling is to provide assurance that the adjacent upland land disturbing activities are conducted in a manner that does not cause an impact to the nearby stream. The upstream sampling point shall serve as the baseline condition for each particular monitoring event at each sampling location.

A map depicting the recommended nine (9) stream monitoring locations is included in Appendix A. Each map depicts the suggested sampling points. During the initial pre-construction monitoring, Mountain Valley shall select an exact point appropriate to existing field conditions and shall locate them with sub-meter GPS survey equipment for future monitoring events. If allowed by the landowner, a permanent survey marker shall also be installed.

Mountain Valley will make commercially reasonable attempts to obtain access for these monitoring locations. If access is limited (i.e., biological monitoring requires at least 300 feet for each sample reach, so some landowners may not concur with that element of the monitoring), or if access is denied, the monitoring program will be adjusted accordingly after consultation with DEQ.

4.0 Monitoring Parameters

The following monitoring parameters are recommended (Table 3):

Table 3: Monitoring Parameters
Chemical Parameters
Temperature
Dissolved Oxygen
Specific conductance
pH
Turbidity (NTU's)
Physical Parameters
Photo documentation, general observations
Biological
Family-level macroinvertebrate monitoring

5.0 Monitoring Frequency

Mountain Valley will conduct monitoring of chemical and physical parameters at each identified location three times prior to construction, three times during active construction, and three times after stabilization (i.e., seeding and mulching of the construction right-of-way). Sample events will be conducted a minimum of 1 week apart. Biological sampling will occur once at pre-, during, and post-construction, provided that the sampling can occur within the spring or fall index period (March 1 through May 31 and September 1 through November 30). The post-construction benthic sampling will occur at least a month after construction completion and ground stabilization, provided that sampling can occur within the spring or fall index period, otherwise sampling will take place in the first available index period.

6.0 Monitoring Methodology

Sampling of Chemical and Physical Parameters will be performed in-situ; collection of samples for laboratory analysis is not proposed because it is not practicable for these chemical parameters. Biological sampling will be performed in the field with laboratory analysis of the collected specimens (i.e., sample sorting and identification). The sampling parameters will be recorded as follows (Table 4):

Table 4: Sampling Methodology	
Chemical Parameters	Sampling Methodology
Temperature	*YSI 556 PRO PLUS Multi Probe System (MPS), or similar*
Dissolved Oxygen	*YSI 556 PRO PLUS Multi Probe System (MPS), or similar*
Specific conductance	*YSI 556 PRO PLUS Multi Probe System (MPS), or similar*
pH	*YSI 556 PRO PLUS Multi Probe System (MPS), or similar*
Turbidity (NTU's)	*LaMotte 2020we/wi Turbidimeter, or similar*
Physical Parameters	
Photo documentation, general observations	*GPS-enabled camera. Photos will have unique ID, date, and GPS coordinates. Photo stations will be staked in the field. General observations will also be recorded (i.e., weather, stream conditions)*
Biological Parameters	
Family-level macroinvertebrate monitoring	*EPA's Rapid Bioassessment Protocol*[6] *and A Stream Condition Index for Virginia Non-Coastal Stream*[7]

[6] Barbour, M.T., J. Gerritsen, and B.D. Snyder and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and rivers; periphyton, benthic macroinvertebrates, and fish 2nd edition. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA841-b-99-002.

[7] Tetra Tech, Inc. 2003. A Stream Condition Index for Virginia Non-Coastal Streams. Tetra Tech, Inc. Owings Mills,

7.0 Handling and Analytical QA/QC Procedures

Chemical/Physical Parameters:

All equipment will be calibrated prior to use in accordance with the manufacturer specifications, or according to the best professional judgment of the staff conducting the samples. A calibration log will be kept and made available upon request. Specific calibration protocols for the YSI 556 PRO PLUS Multi Probe System and the LaMotte 2020we/wi Turbidimeter are included in Appendix B. A daily equipment check prior to use will be performed to ensure good working order. “Emergency repair kits” for all equipment will be kept on-hand in the field during sampling events.

In order to address QA/QC concerns, all measurements will be taken via independent simultaneous sampling. Two staff members with identical equipment will perform the sampling simultaneously at each determined location to ensure that the results are accurate between calibrated equipment. This protocol will also guard against unexpected equipment failures.

Biological Parameters:

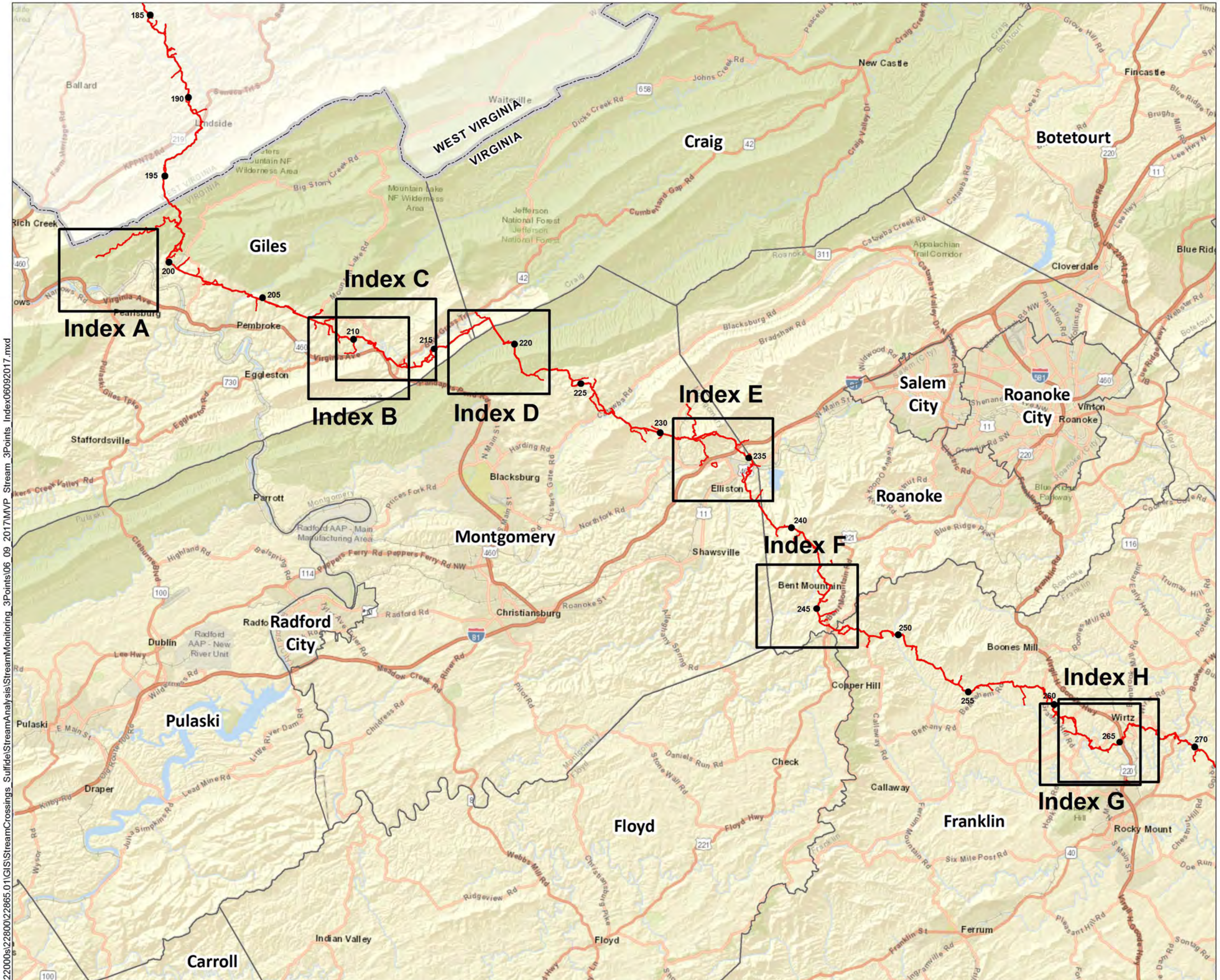
Biological sampling, sorting, identification and reporting will be conducted in accordance with the DEQ-approved Quality Assurance Project Plan (QAPP). A copy of the QAPP is included in Appendix C. MVP will contact the DEQ QA officer to visit at least one sampling event. A schedule of sampling events will be provided to DEQ at least one week prior to each sampling period. A sampling of random benthic specimens from the sampling locations will be provided by the processing laboratory.

8.0 Reporting Procedures

Within 4 weeks of completing the sampling event the data (chemical results, bench sheets, metrics, and VSCI scores) will be provided by email to the address identified by DEQ. All data will be provided in PDF and Microsoft Excel file formats. Photographic information will be provided in a PDF and Microsoft Word file formats. Emails will be sent with a “read receipt” to confirm delivery.

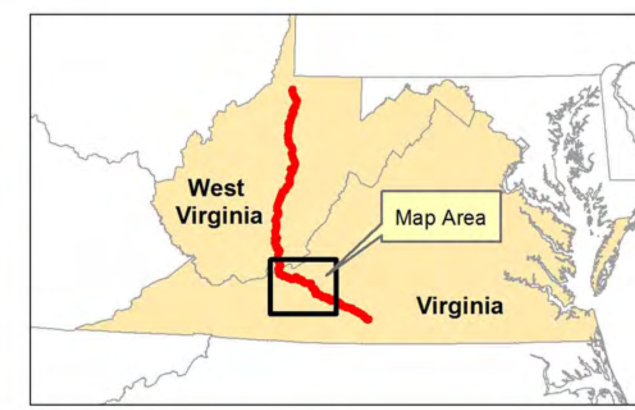
If the monitoring during or following construction produces elevated or anomalous sample results that exceed the applicable water quality criteria, MVP will initiate consultation with DEQ within 5 business days of such sampling to determine an appropriate response.

Maryland. Prepared for Virginia Department of Environmental Quality, Richmond, Virginia



Index Sheet:
Potential Stream Monitoring Locations

- MVP Pipeline Limits of Disturbance
- MVP Mile Marker (5 mile increments)
- Index Sheet
- County Boundary
- State Boundary



NORTH

0 3 6 12 Miles

Basemap Source: ESRI ArcGIS Online. US Topo.
Boundary Source: Tetra-Tech. May 15, 2017.

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Index Area A: Potential Stream Monitoring Locations

ID	Longitude	Latitude
1D	-80.7415	37.3618
1M	-80.7332	37.3715
1U	-80.7227	37.3751

- MVP Pipeline Limits of Disturbance
- MVP Mile Marker
- Potential Stream Monitoring Locations
- National Hydrologic Dataset (NHD) Streams
- Trout Streams
- Reservoirs Listed as Public Water Supply
- Streams Listed as Public Water Supply
- Sulfide Hazard Areas

Data Sources:
- Trout Streams: VA DEQ Water Monitoring and Assessment Program. www.deq.virginia.gov/Programs/Water.aspx. And VA DGIF Cold Water Stream Survey (CWSS) https://www.dgif.virginia.gov/gis/data/.
- Sulfide Hazard: Virginia Tech - Dept. of Crop and Soil Environmental Sciences. Zenah W. Orndorff, and W. Lee Daniels.
- Public Water Supply: Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report.

NORTH

0 0.25 0.5 1 Miles

Basemap Source: ESRI ArcGIS Online. US Topo.
Boundary Source: Tetra-Tech. May 15, 2017.

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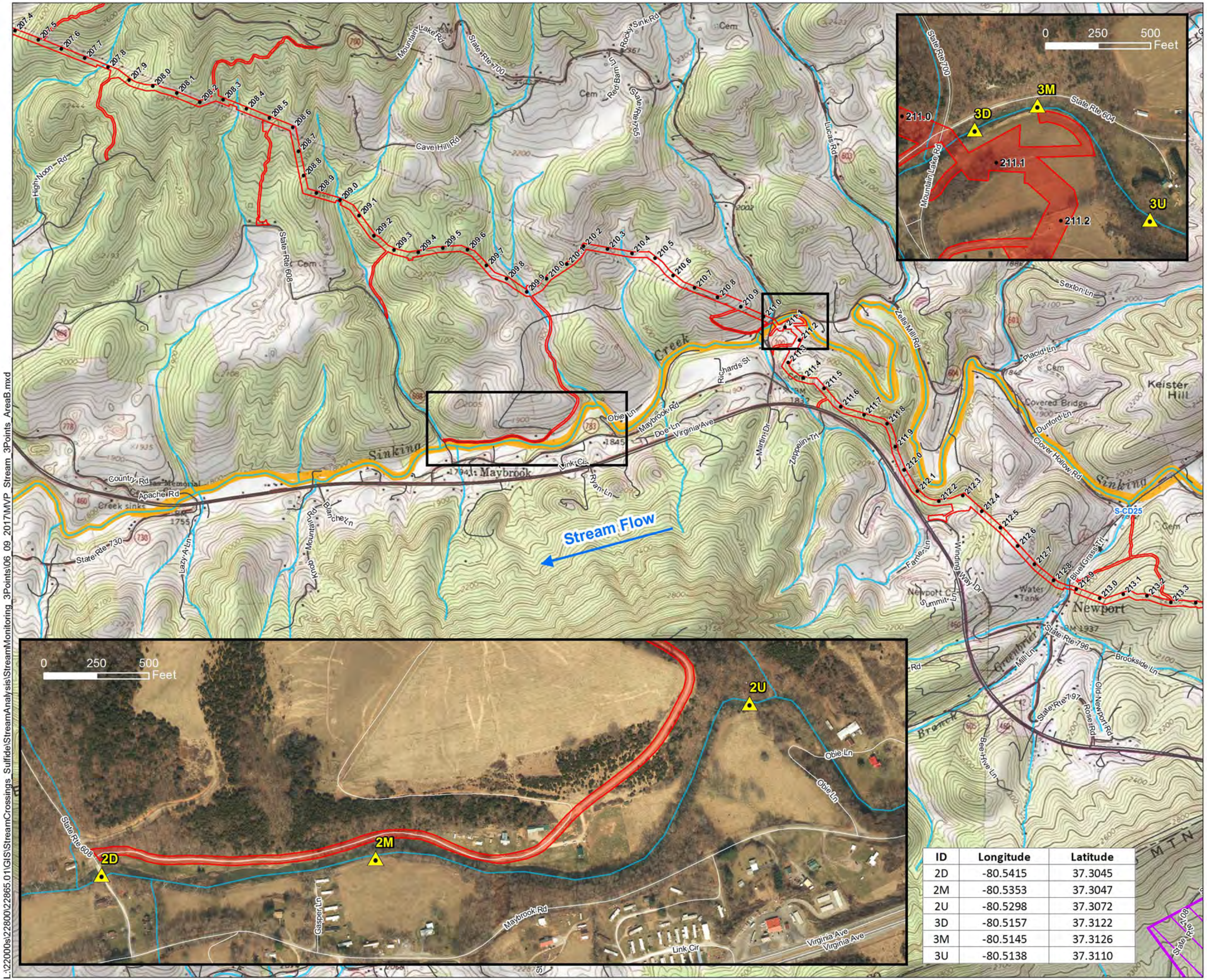

ID	Longitude	Latitude
2D	-80.5415	37.3045
2M	-80.5353	37.3047
2U	-80.5298	37.3072
3D	-80.5157	37.3122
3M	-80.5145	37.3126
3U	-80.5138	37.3110

Index Area B: Potential Stream Monitoring Locations

- MVP Pipeline Limits of Disturbance
- MVP Mile Marker
- Potential Stream Monitoring Locations
- National Hydrologic Dataset (NHD) Streams
- Trout Streams
- Reservoirs Listed as Public Water Supply
- Streams Listed as Public Water Supply
- Sulfide Hazard Areas

Data Sources:
- Trout Streams: VA DEQ Water Monitoring and Assessment Program. www.deq.virginia.gov/Programs/Water.aspx. And VA DGIF Cold Water Stream Survey (CWSS) https://www.dgif.virginia.gov/gis/data/.
- Sulfide Hazard: Virginia Tech - Dept. of Crop and Soil Environmental Sciences. Zenah W. Orndorff, and W. Lee Daniels.
- Public Water Supply: Final 2014 305(b)/303(d) Water Quality Assessment

NORTH

0 0.25 0.5 1 Miles

Basemap Source: ESRI ArcGIS Online. US Topo.
Boundary Source: Tetra-Tech. May 15, 2017.

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Index Area C: Potential Stream Monitoring Locations

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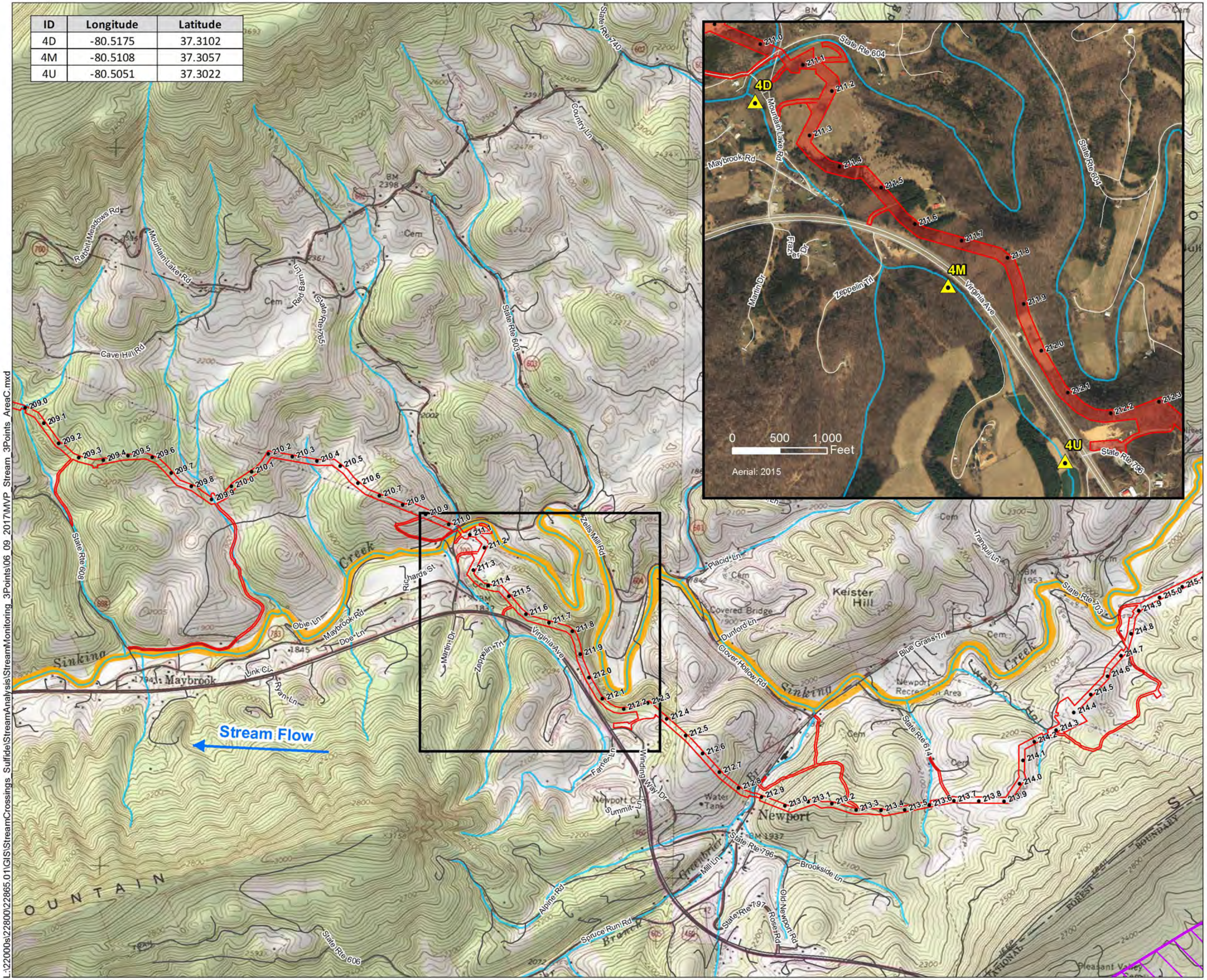
4M	-80.5108	37.3057
4U	-80.5051	37.3022



- MVP Pipeline Limits of Disturbance
- MVP Mile Marker
- Potential Stream Monitoring Locations
- National Hydrologic Dataset (NHD) Streams
- Trout Streams
- Reservoirs Listed as Public Water Supply
- Streams Listed as Public Water Supply
- Sulfide Hazard Areas

Data Sources:
- Trout Streams: VA DEQ Water Monitoring and Assessment Program. www.deq.virginia.gov/Programs/Water.aspx. And VA DGIF Cold Water Stream Survey (CWSS) https://www.dgif.virginia.gov/gis/data/.
- Sulfide Hazard: Virginia Tech - Dept. of Crop and Soil Environmental Sciences. Zenah W. Orndorff, and W. Lee Daniels.
- Public Water Supply: Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report.

NORTH

0 0.25 0.5 1 Miles

Basemap Source: ESRI ArcGIS Online. US Topo.
Boundary Source: Tetra-Tech. May 15, 2017.

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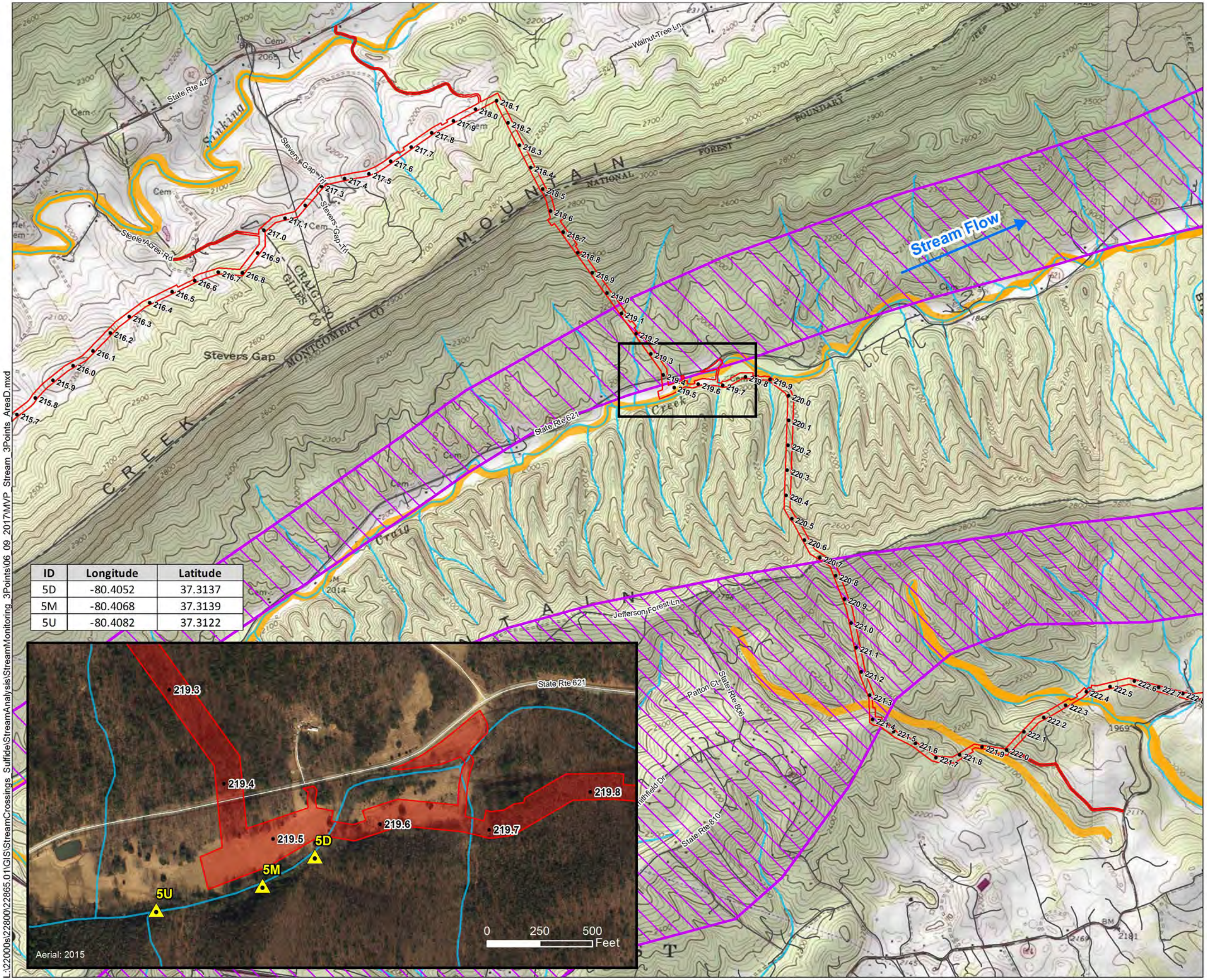
Index Area D: Potential Stream Monitoring Locations



ID	Longitude	Latitude
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5M	-80.4068	37.3139
5U	-80.4082	37.3122

- MVP Pipeline Limits of Disturbance
- MVP Mile Marker
- Potential Stream Monitoring Locations
- National Hydrologic Dataset (NHD) Streams
- Trout Streams
- Reservoirs Listed as Public Water Supply
- Streams Listed as Public Water Supply
- Sulfide Hazard Areas

Data Sources:
- Trout Streams: VA DEQ Water Monitoring and Assessment Program. www.deq.virginia.gov/Programs/Water.aspx. And VA DGIF Cold Water Stream Survey (CWSS) https://www.dgif.virginia.gov/gis/data/.
- Sulfide Hazard: Virginia Tech - Dept. of Crop and Soil Environmental Sciences. Zenah W. Orndorff, and W. Lee Daniels.
- Public Water Supply: Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report.

NORTH

0 0.25 0.5 1 Miles

Basemap Source: ESRI ArcGIS Online. US Topo.
Boundary Source: Tetra-Tech. May 15, 2017.

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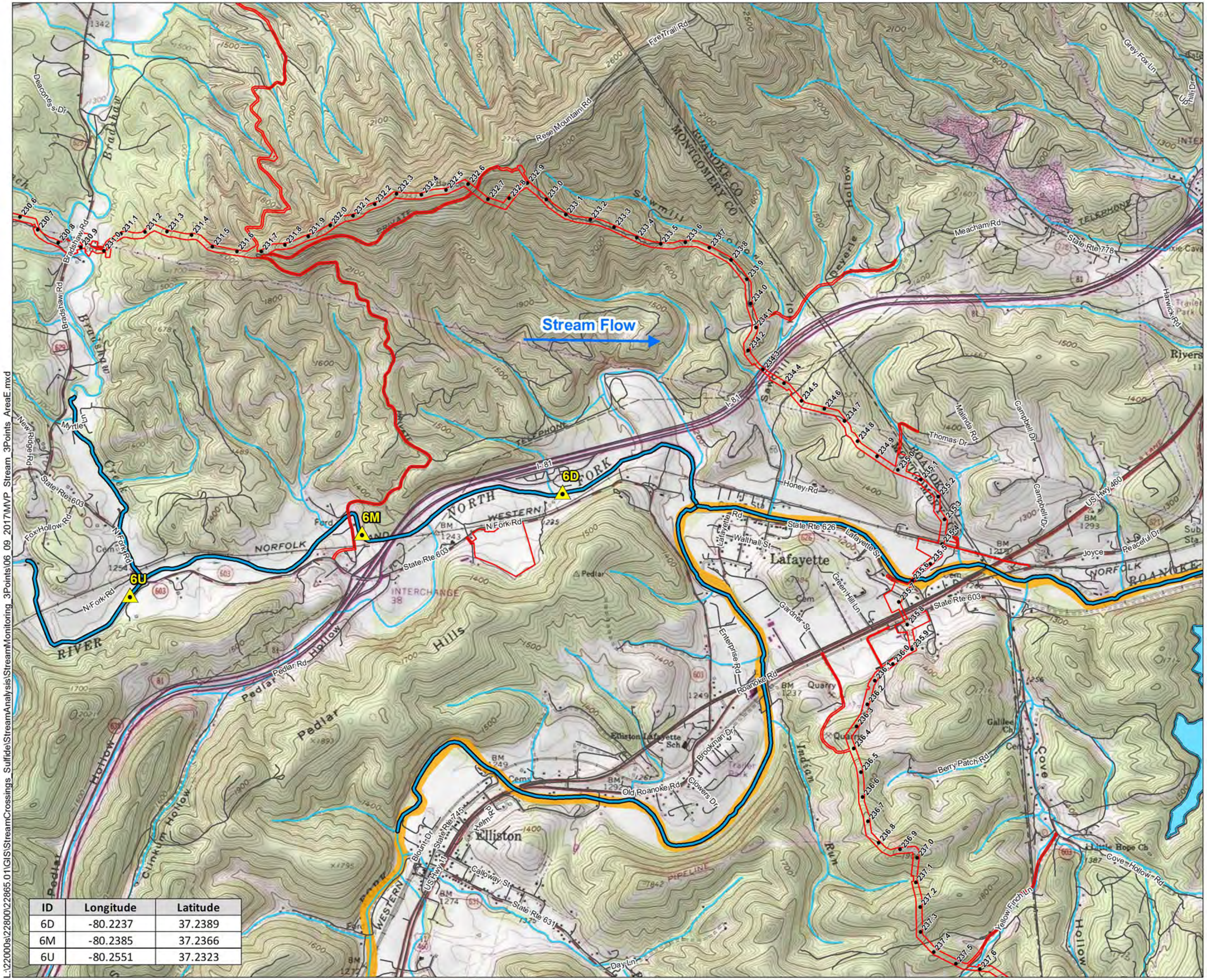
Index Area E: Potential Stream Monitoring Locations



ID	Longitude	Latitude
6D	-80.2237	37.2389
6M	-80.2385	37.2366
6U	-80.2551	37.2323

- MVP Pipeline Limits of Disturbance
- MVP Mile Marker
- Potential Stream Monitoring Locations
- National Hydrologic Dataset (NHD) Streams
- Trout Streams
- Reservoirs Listed as Public Water Supply
- Streams Listed as Public Water Supply
- Sulfide Hazard Areas

Data Sources:
- Trout Streams: VA DEQ Water Monitoring and Assessment Program. www.deq.virginia.gov/Programs/Water.aspx. And VA DGIF Cold Water Stream Survey (CWSS) https://www.dgif.virginia.gov/gis/data/.
- Sulfide Hazard: Virginia Tech - Dept. of Crop and Soil Environmental Sciences. Zenah W. Orndorff, and W. Lee Daniels.
- Public Water Supply: Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report.

NORTH

0 0.25 0.5 1 Miles

Basemap Source: ESRI ArcGIS Online. US Topo.
Boundary Source: Tetra-Tech. May 15, 2017.

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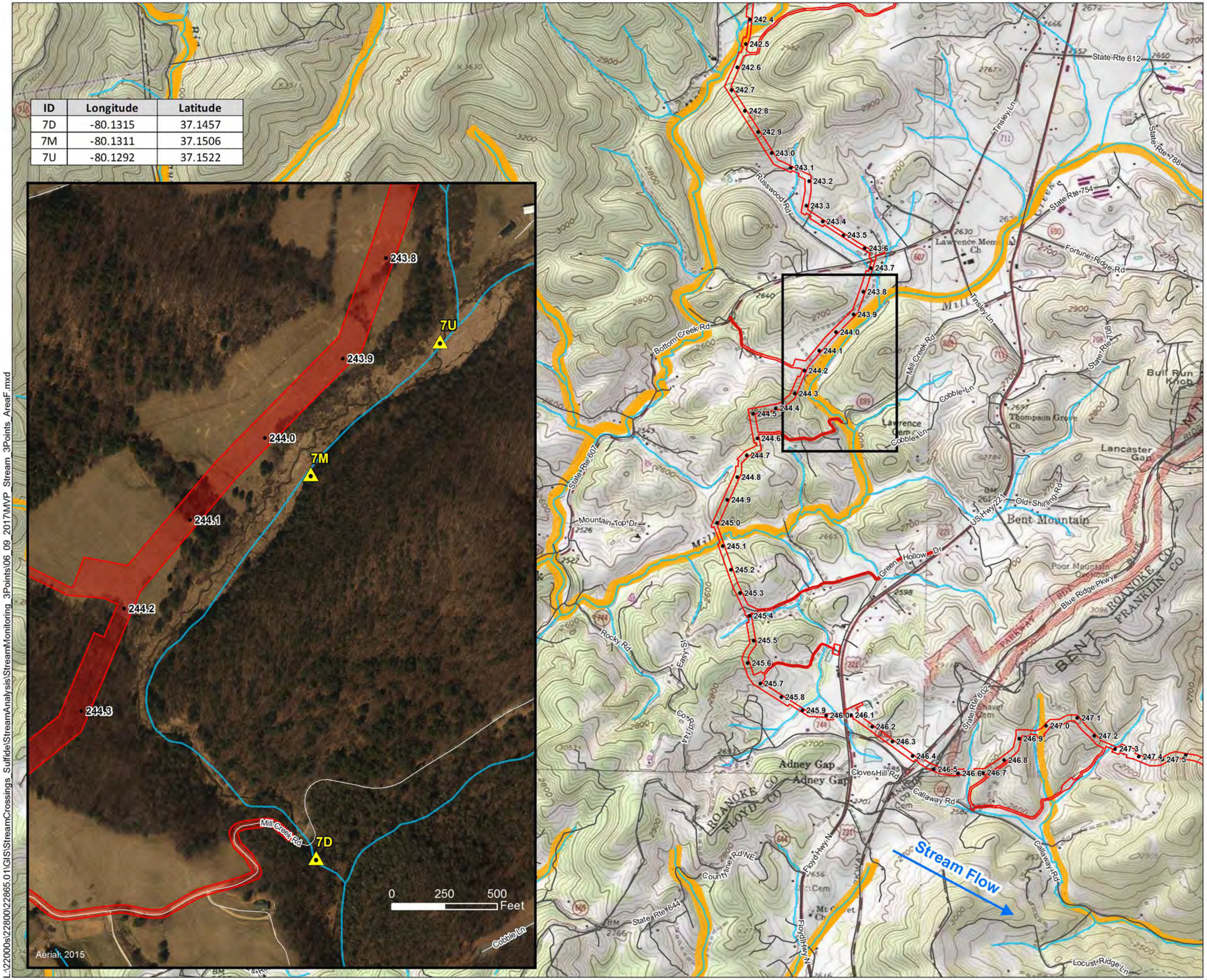
Index Area F: Potential Stream Monitoring Locations

ID	Longitude	Latitude
7D	-80.1315	37.1457
7M	-80.1311	37.1506
7U	-80.1292	37.1522



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- MVP Pipeline Limits of Disturbance
- MVP Mile Marker
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- Streams Listed as Public Water Supply
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- Public Water Supply: Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report.

NORTH

0 0.25 0.5 1 Miles

Basemap Source: ESRI ArcGIS Online. US Topo.
Boundary Source: Tetra-Tech. May 15, 2017.

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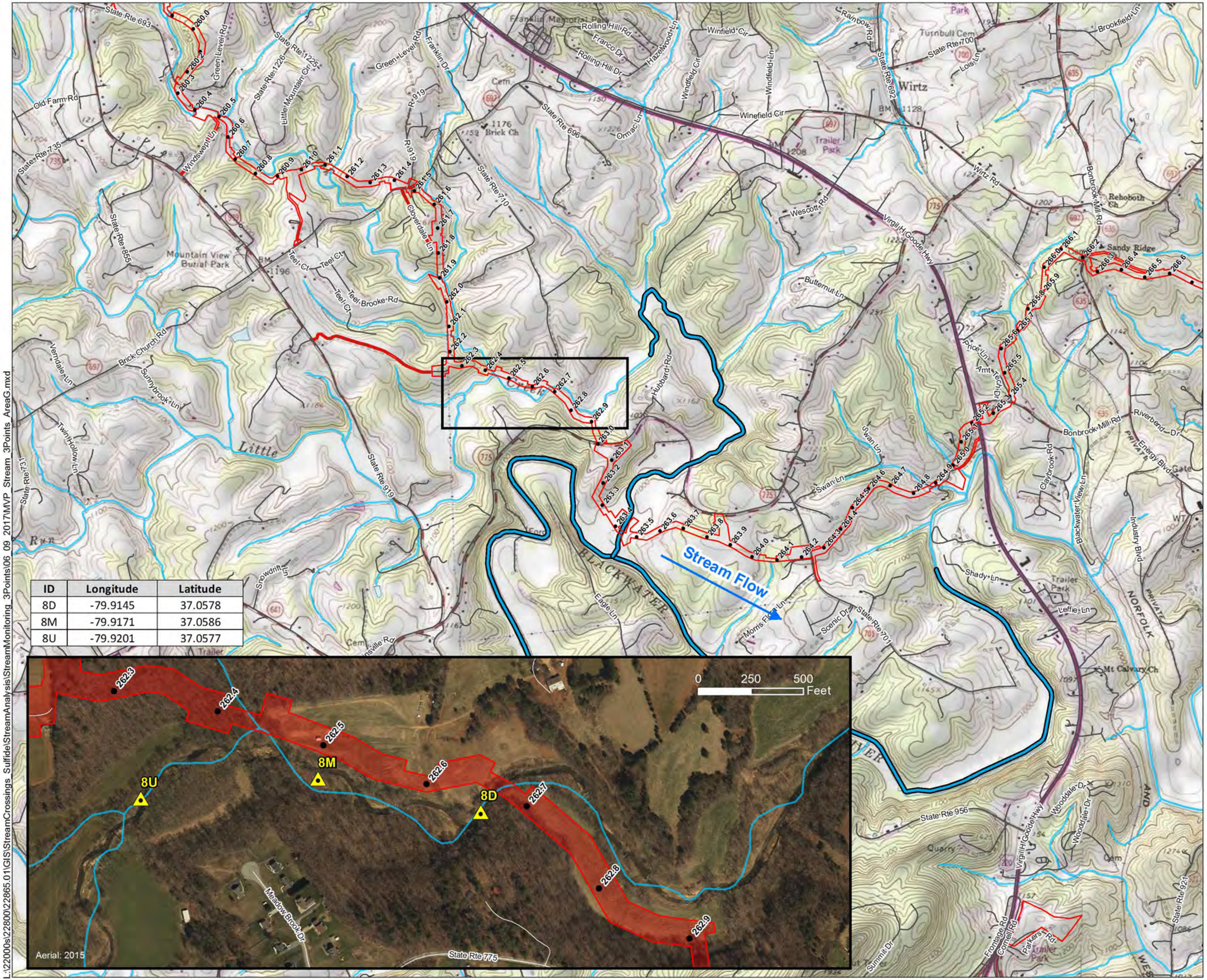
Index Area G:
Potential Stream Monitoring Locations



ID	Longitude	Latitude
8D	-79.9145	37.0578
8M	-79.9171	37.0586
8U	-79.9201	37.0577

- MVP Pipeline Limits of Disturbance
- MVP Mile Marker
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- Streams Listed as Public Water Supply
- Sulfide Hazard Areas

Data Sources:
- Trout Streams: VA DEQ Water Monitoring and Assessment Program. www.deq.virginia.gov/Programs/Water.aspx. And VA DGIF Cold Water Stream Survey (CWSS) https://www.dgif.virginia.gov/gis/data/.
- Sulfide Hazard: Virginia Tech - Dept. of Crop and Soil Environmental Sciences. Zenah W. Orndorff, and W. Lee Daniels.
- Public Water Supply: Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report.

NORTH

0 0.25 0.5 1 Miles

Basemap Source: ESRI ArcGIS Online. US Topo.
Boundary Source: Tetra-Tech. May 15, 2017.

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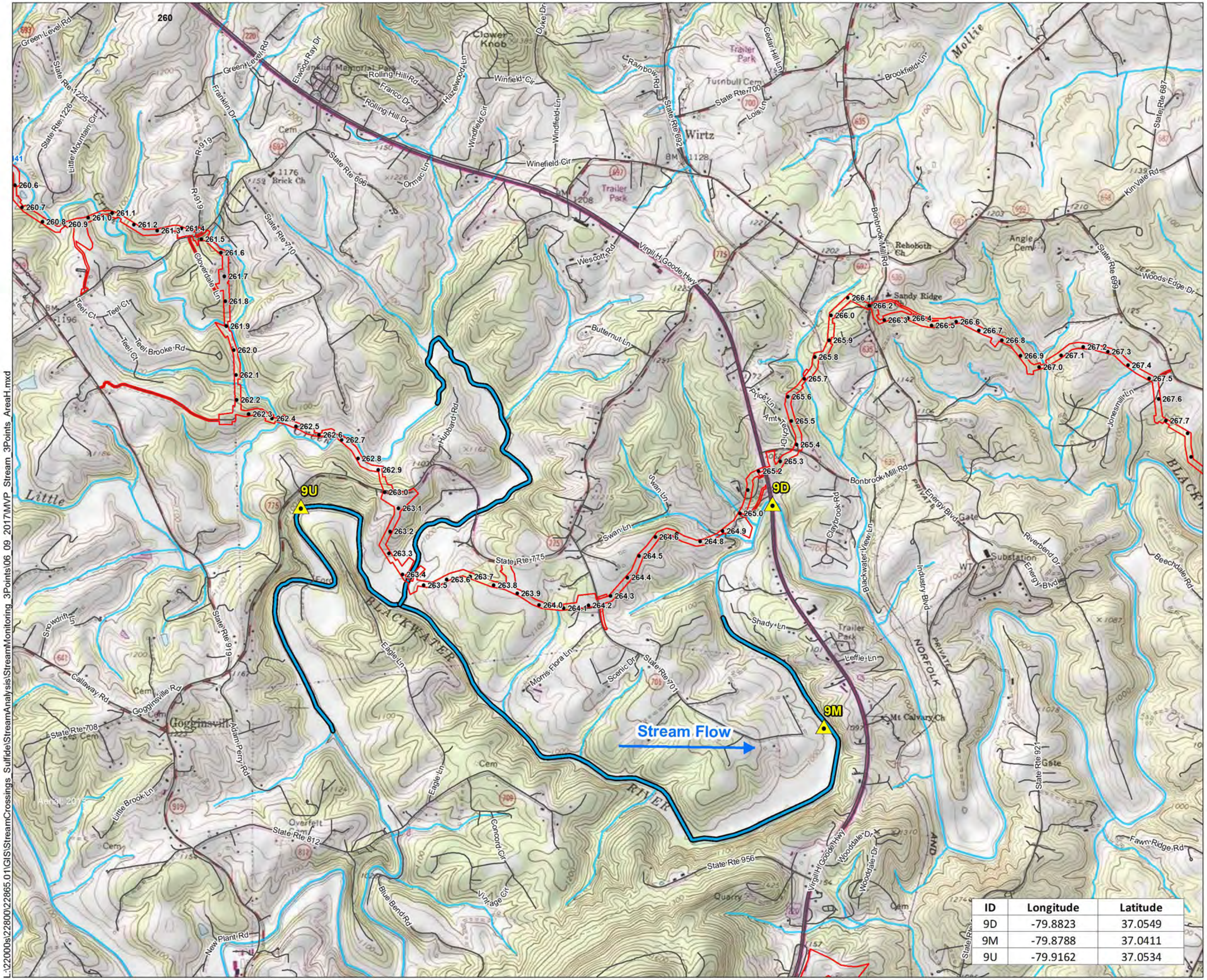
Index Area H: Potential Stream Monitoring Locations



ID	Longitude	Latitude
9D	-79.8823	37.0549
9M	-79.8788	37.0411
9U	-79.9162	37.0534

- MVP Pipeline Limits of Disturbance
- MVP Mile Marker
- Potential Stream Monitoring Locations
- National Hydrologic Dataset (NHD) Streams
- Trout Streams
- Reservoirs Listed as Public Water Supply
- Streams Listed as Public Water Supply
- Sulfide Hazard Areas

Data Sources:
- Trout Streams: VA DEQ Water Monitoring and Assessment Program. www.deq.virginia.gov/Programs/Water.aspx. And VA DGIF Cold Water Stream Survey (CWSS) https://www.dgif.virginia.gov/gis/data/.
- Sulfide Hazard: Virginia Tech - Dept. of Crop and Soil Environmental Sciences. Zenah W. Orndorff, and W. Lee Daniels.
- Public Water Supply: Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report.

NORTH

0 0.25 0.5 1 Miles

Basemap Source: ESRI ArcGIS Online. US Topo.
Boundary Source: Tetra-Tech. May 15, 2017.

Mountain Valley PIPELINE

Wetland Studies and Solutions, Inc.
a DAVEY company

L:\22000s\22800\22865.01\GIS\StreamCrossings_Sulfide\StreamAnalysis\StreamMonitoring_3Points\06_09_2017\MVP_Stream_3Points_AreaH.mxd

Appendix B
Instrument Maintenance and Calibration Procedures

This exhibit outlines specific notes and calibration procedures for the water chemistry instruments utilized in WSSI's water quality monitoring program. Consult the Safety Data Sheets (SDS) for the calibration solutions as some products may be irritants and follow the disposal instructions for each solution.

1. **LaMotte 2020we/wi Turbidimeter**

   Notes:
   - Refer to the user manual for start-up instructions and factory reset options.
   - This meter can be used in the field on battery power; however, the preferred method of use is in the laboratory.

   Product Calibration:
   - For the most accurate results, perform a calibration over the smallest range possible.
   - Use a calibration standard that, along with the blank, brackets the range of the samples that will be tested. Consult user manual for further clarification.
   - It is recommended that this meter be calibrated daily when being used daily.
   - With the meter ON, select "MEASURE"
   - Select "TURBIDITY—WITH BLANK"
   - Rinse a sampling tube three times with 0 NTU Standard. Fill the tube to the link with the 0 NTU Standard. Cap the tube. This is the BLANK.
   - Wipe the tube thoroughly with a Kimtech Kimwipe, or a lint-free cloth.
   - Insert the tube into the chamber with the index line on the tube aligned with the index arrow on the meter. Close the lid. Scan Blank. Remove the tube.
   - After scanning the blank, scan the blank again as a sample. It should read 0.00. If not, reblank the meter and scan the blank again. Repeat until it reads 0.00. A small negative number will be observed if the reading is slightly less than the reading used as the blank. This is expected due to minute variations between readings.
   - Empty the tube. Rinse the sample three times with the 1 NTU Standard. Fill the tube with 1 NTU Standard and cap the tube.
   - For the most accurate results, the same tube should be used for the Blank, the 1 NTU Standard and the Sample to eliminate error caused by tube to tube variation.
   - Fill the tube slowly with a pipette, pouring down the inside wall of the tube to avoid introducing bubbles.
   - Wipe the tube thoroughly with a Kimtech Kimwipe, or a lint-free cloth. Insert the tube into the chamber. Close the lid and scan the sample.

- Scan the sample three times, removing the tube from the chamber after each scan. The readings should be consistent. Use the last consistent reading to calibrate the meter.
- Press the DOWN arrow. Select "CALIBRATE"
- Press the UP or DOWN arrow to change the turbidity reading on the display to read **1.00**.
- Press "ENTER" to set calibration.

2. YSI 556 PRO PLUS Multi Probe System (MPS)

Notes:

- Refer to the user manual for instructions on assembling the unit.
- When unit is not in use for up to 30 days, store electrodes in calibration/transport sleeve with sponge soaked in distilled water to provide 100% saturated air environment.
- When unit is not in use for ≥30 days, remove the dissolved oxygen membrane cap, thoroughly rinse the sensor, dry, and use a clean, dry new membrane cap to screw over the sensor to keep it dry and to protect the anode and cathode. Additionally, store pH electrode in the small pH 7 solution bottle to provide a saturated air environment (provided by YSI on delivery, with solution already in it). Then, store all electrodes dry in calibration cup or Probe Sensor Guard (See manual for more specific instructions).
- Replace electrolyte solution in membrane cap every 2-8 weeks when being used daily.
- When taking water quality readings in the field, always use probe sensor guard to protect electrodes.
- Conductivity Calibrator solution should be stored between 0 and 30°C. Discard unused solution one month after opening.
- There are no specifications for pH storage temperature. Therefore, it can be stored at room temperature. Read label for expiration dates.

Product Calibration:

a. *Dissolved oxygen*

- The YSI offers 3 methods that can be used to calibrate DO; first using air calibration in % saturation; second calibrates in mg/L to a solution with a known DO concentration (either of these methods will automatically calibrate the other); third is a zero calibration (in which you have to perform either the % or mg/L calibration following).
- The following is the % saturation calibration (easiest).
    i. Moisten the sponge in the cal/transport sleeve and loosely screw onto probes to provide contact with atmosphere. **Make sure the DO and temperature sensors are NOT immersed in the water.**

1. Press on/off button
2. Use "Cal" hot key then highlight DO, then press Enter
4. Highlight DO%, then press Enter
5. Verify barometric pressure. Once DO and temperature are stable, highlight Accept Calibration and press Enter. The screen will indicate that the calibration was accepted.

b. *Conductivity*

1. Select "Cal" hot key on keypad
2. Using the arrows, highlight "Conductivity", and press enter
3. Pick from the options for calibrating Specific Conductance, Conductivity, or Salinity (calibrating one will automatically calibrate the others). Additionally, you will have to choose the units you want conductivity displayed in.
4. Fill cal/transport cup completely with conductivity solution and gently place probes in and tighten to ensure there are no bubbles in solution.
7. Allow approximately 1 minute for temperature to stabilize
8. Highlight the Calibration Value and enter the known conductivity of the solution into the YSI.
9. When the readings stabilize, highlight Accept Calibration and press Enter. The screen will indicate that the calibration was accepted. Press Enter again
10. Press escape to return to the calibrate menu
11. Clean the calibration cup and electrodes with water and dry completely

c. *pH*

1. Select "Cal" hot key on keypad
2. Using the arrows, highlight "pH", then press Enter. The pH calibration allows up to a 6 point calibration.
3. Place enough of the buffer solution in the cal/transport cup to cover the pH probes and insert probes into cal/transport cup.
4. Once reading is stable, highlight Accept Calibration and press Enter
5. Screen will read Ready for Second Point and the process will repeat.
6. **Press "Cal" to complete calibration** after reaching desired number of buffer calibrations or press Esc to cancel the calibration.

Field Setup and Use:

Remove the unit from storage and replace the cal/transport cup with the guard cup.

1. Turn on. The instrument will be in Run mode when powered on.

2. Connect the two ends of the data cable to the probe and instrument.

3. To take readings, insert the probe into the stream, perpendicular to the flow, until all the sensors are covered. Keeping the probes submerged; agitate the probe gently until the readings stabilize. This releases any air bubbles and provides movement if measuring DO.

5. Turn the instrument off and remove the guard and replace the cal/transport cup on the probes.

End of Day Checks:

Note: DO NOT CALIBRATE THE INSTRUMENT TO THE STANDARD VALUES DURING POST CALIBRATION CHECKS. Perform post calibration before cleaning up and servicing the sensor. When performing the post calibration of the system, it is extremely important that all calibration solutions are at thermal equilibrium.

Dissolved Oxygen

1. Upon returning from the field, allow the instrument to equilibrate to room temperature. Once the temperature has stabilized, add a small quantity of fresh laboratory grade (or distilled) water into the probe and cap shut. Carefully blot dry any water droplets on the membrane sensor.

3. While the probe is adjusting, obtain the barometric pressure of the laboratory and calculate the barometric pressure correction factor. (See "Correction Factor for Barometric Pressure").

4. Once the temperature reading has stabilized (about 10 seconds between changing to the tenths place (0.1), calculate the theoretical dissolved oxygen value and multiply by the barometric pressure correction factor. Enter this into the saturated (theoretical) end of day dissolved oxygen check on the calibration log sheet. (see "How to Calculate Theoretical Dissolved Oxygen Values")

5. Record the dissolved oxygen reading on the probe in the end of day dissolved oxygen field on the YSI Multiprobe Calibration and Post Calibration Log. If the difference between the two is less than 0.5 mg/L the instrument is in calibration. If the difference between the Saturated DO value and the instrument indicates that the instrument is not in calibration, check again the next morning to make sure that the temperature was properly equilibrated. If the difference is still greater than 0.5 mg/L the data collected during the sampling event is suspect and should be flagged. Additionally, the instrument should not be utilized until more extensive cleaning/maintenance is conducted and the instrument calibrates well.

Specific Conductance

Note: Readings are most accurate when they lie within the calibrated range. Determine the expected range of values in the field prior to calibration.

1. Rinse the sensors twice with a small portion of the specific conductance standard, discarding the rinse each time.

2. Fill calibration cup with fresh standard solution and screw on cal/transport cup making sure that there are no bubbles in the cup.

3. Watch the specific conductance readings until they have stabilized.

4. Record the reading on the YSI Multiprobe Calibration and Post Calibration Log.

5. Compare the displayed value to the standard value and calculate the difference. If the difference is less than ±10% of 50,000 µs/cm standard then the instrument is in calibration. If the instrument is not in calibration, check again the next morning to make sure that the temperature was properly equilibrated. If the difference is still out specification, the data is suspect and should be flagged. Additionally, the YSI should not be utilized for that parameter until it has an extensive cleaning/maintenance.

pH

1. Rinse twice with a small amount of pH 7.0 buffer saved from previous calibrations to saturate the sensors. Discard the buffer after each rinse.

2. Fill cup with Fresh pH 7.0 buffer sufficient to cover the sensor.

3. Allow two minutes for thermal equilibrium. Record the pH value displayed in the YSI Multiprobe Calibration and Post Calibration Log.

4. Discard the 7.0 buffer used to do the end of day check down the drain.

5. Flush the calibration cup and sensors thoroughly twice with laboratory grade (or distilled) water.

6. Rinse the cup and sensors twice with a small amount of pH 10.00 or pH 4.00 buffer.

7. Fill the calibration cup with FRESH pH 10.00 or pH 4.00 buffer to cover the sensor and wait for the instrument to equilibrate.

8. Record the pH value displayed in the YSI Multiprobe Calibration and Post Calibration Log.

9. Replace the storage cup.

10. Compare the displayed values to the standard values. If the difference between the standard utilized and the value displayed is ± 0.2 units the pH is in calibration. If the difference indicates that the instrument is not in calibration, check again the next morning to make sure that the temperature was properly equilibrated. If the difference is still greater than 0.2 units the data is suspect and should be flagged. Additionally, the YSI should not be utilized for that parameter until it has an extensive cleaning/maintenance.

How to Calculate Theoretical Dissolved Oxygen Values (obtained from DEQ standard operating procedures)

Proper calibration of Dissolved Oxygen (DO) probes is important to collect accurate data. An easy way to see if a probe is calibrated correctly is to compare the probe's results against the theoretical DO value. This DO value is dependent on temperature and barometric pressure.

DO Level Based on Temperature

The top table on the attached chart allows users to find the DO level based on temperature. The top and side axis of the table corresponds to the temperature that the probe is reporting. The intersection of these two axes displays the DO reading. Write this number down to start calculating the theoretical DO level.

Correction Factor for Barometric Pressure

Barometric pressure measures how much atmosphere is pressing down on a surface. Weather systems and elevation above (or below) sea level can change this value. The bottom table of the attached chart will help compensate for these changes in pressure. Dissolved oxygen probes normally show pressure in millimeters of mercury (**mmHg**) or millibars (**mBar**).

Having a barometer on hand is a good way to get pressure data. A weather station can also provide this information. Websites such as www.wunderground.com are useful to find nearby stations. Please note that most barometers and weather stations report pressure in inches of mercury (**inHg**).

> **Note: Using Weather Station Barometric Pressure Readings**
>
> Weather stations standardize barometric pressure readings to make it appear as if the station is at sea level. To account for this, subtract the barometric pressure reading by 1.01 inHg per 1,000 feet in elevation of the weather station. This final value is known as **absolute barometric pressure (ABP)**.
>
> **Example**: Find the absolute barometric pressure of a station located 222 feet above sea level that reported 30.12 inHg.
>
> $30.12\text{ inHg} - \frac{1.01\text{ inHg}}{1000/\,222\text{ feet}} \rightarrow 30.12 - \frac{1.01}{4.50} \rightarrow 30.12 - 0.22 = 29.90\text{ inHg ABP}$

Once identifying local pressure, use the bottom table to find the proper correction factor to use. The formulas at the bottom of the chart will help in converting inHg barometric pressure reading into mBar (or mmHg) used by the probe. Use this value to find the correction factor to use in the final calculation.

Example: A barometric pressure of 970 millibars you would use a correction factor of 0.96 (second column, bottom row).

Theoretical DO Calculation

To find the theoretical DO value, use the following formula.

Theoretical DO = (DO level based on temperature) x (barometric pressure correction factor)

Example: If a probe had a temperature of 18.4 C and the barometric pressure was 970 mBar, the theoretical DO value would be 9.00 mg/L (9.37mg/L x 0.96 correction factor)

DEQ Dissolved Oxygen Calibration Sheet

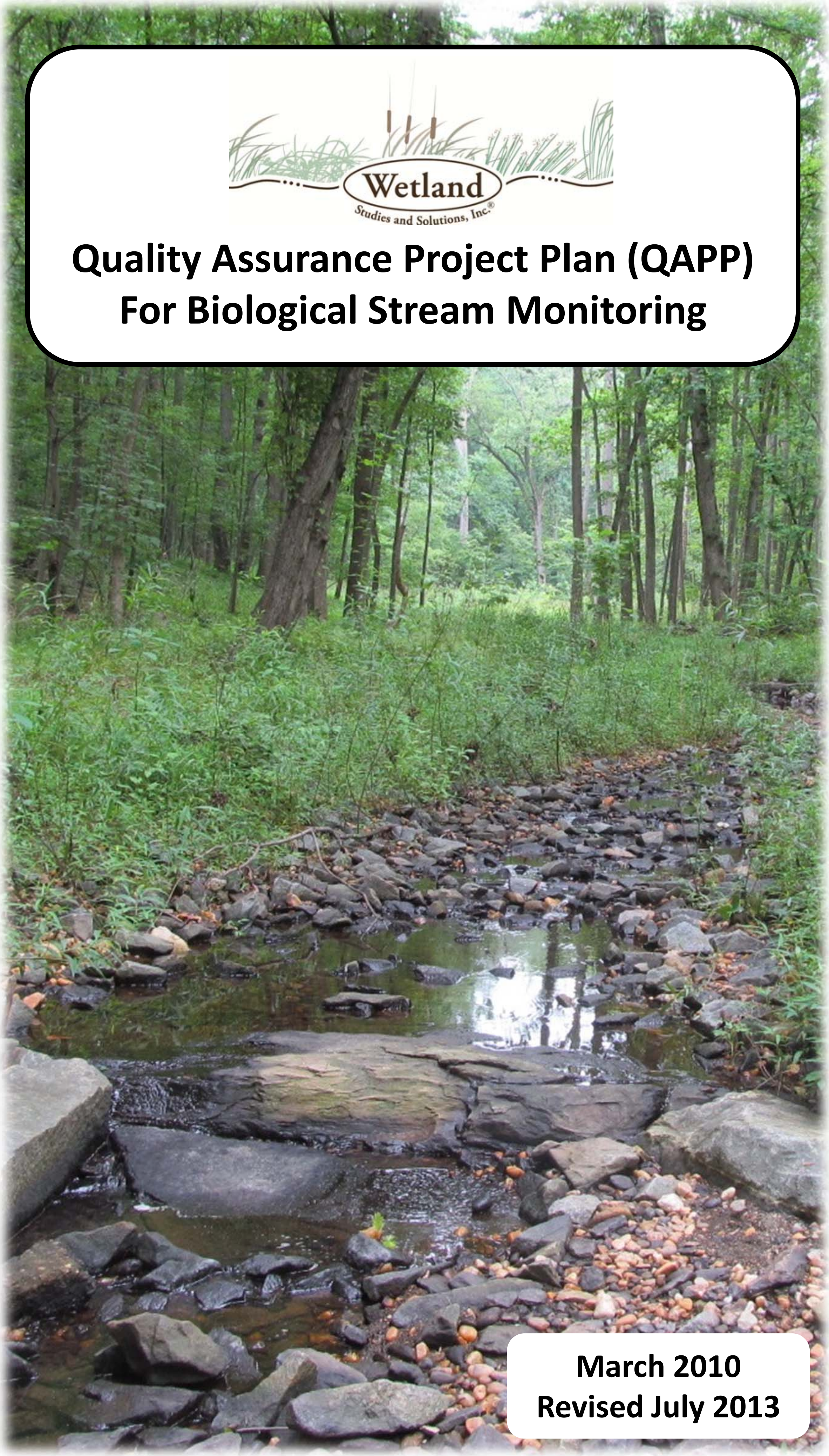
Directions- To calculate the theoretical DO saturation level, multiply the O2 concentration value (found in the top chart) by the barometric pressure correction factor (bottom chart).

Temp in ^{O}C	O_2 concentrations in mg/l									
	0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
5	12.75	12.71	12.68	12.65	12.61	12.58	12.55	12.52	12.48	12.45
6	12.42	12.39	12.36	12.32	12.29	12.26	12.23	12.2	12.17	12.14
7	12.11	12.08	12.05	12.02	11.99	11.96	11.93	11.9	11.87	11.84
8	11.81	11.78	11.758	11.72	11.69	11.67	11.64	11.61	11.58	11.55
9	11.53	11.5	11.47	11.44	11.42	11.39	11.36	11.33	11.31	11.28
10	11.25	11.23	11.2	11.18	11.15	11.12	11.1	11.07	11.05	11.02
11	10.99	10.97	10.94	10.92	10.89	10.87	10.84	10.82	10.79	10.77
12	10.75	10.72	10.7	10.67	10.65	10.63	10.6	10.58	10.55	10.53
13	10.51	10.48	10.46	10.44	10.41	10.39	10.37	10.35	10.32	10.3
14	10.28	10.26	10.23	10.21	10.19	10.17	10.15	10.12	10.1	10.08
15	10.06	10.04	10.02	9.99	9.97	9.95	9.93	9.91	9.89	9.87
16	9.85	9.83	9.81	9.79	9.76	9.74	9.72	9.7	9.68	9.66
17	9.64	9.62	9.6	9.58	9.56	9.54	9.53	9.51	9.49	9.47
18	9.45	9.43	9.41	9.39	9.37	9.35	9.33	9.31	9.3	9.28
19	9.26	9.24	9.22	9.2	9.19	9.17	9.15	9.13	9.11	9.09
20	9.08	9.06	9.04	9.02	9.01	8.99	8.97	8.95	8.94	8.92
21	8.9	8.88	8.87	8.85	8.83	8.82	8.8	8.78	8.76	8.75
22	8.73	8.71	8.7	8.68	8.66	8.65	8.63	8.62	8.6	8.58
23	8.57	8.55	8.53	8.52	8.5	8.49	8.47	8.46	8.44	8.42
24	8.41	8.39	8.38	8.36	8.35	8.33	8.32	8.3	8.28	8.27
25	8.25	8.24	8.22	8.21	8.19	8.18	8.16	8.15	8.14	8.12
26	8.11	8.09	8.08	8.06	8.05	8.03	8.02	8	7.99	7.98
27	7.96	7.95	7.93	7.92	7.9	7.89	7.88	7.86	7.85	7.83
28	7.82	7.81	7.79	7.78	7.77	7.75	7.74	7.73	7.71	7.7
29	7.69	7.67	7.66	7.65	7.63	7.62	7.61	7.59	7.58	7.57
30	7.55	7.54	7.53	7.51	7.5	7.49	7.48	7.46	7.45	7.44

Barometric Pressure Correction factor:

mmHg (mBar)	Corr. Factor	mmHg (mBar)	Corr. Factor	mmHg (mBar)	Corr. Factor	mmHg (mBar)	Corr. Factor
775-771 (1033-1028)	1.02	750-746 (1000-995)	0.987	725-721 (967-961)	0.953	700-696 (934-928)	0.92
770-766 (1027-1021)	1.014	745-741 (994-988)	0.98	720-716 (960-955)	0.947	695-691 (927-921)	0.914
765-761 (1020-1014)	1.007	740-736 (987-981)	0.973	715-711 (954-948)	0.94	690-686 (920-915)	0.907
760-756 (1013-1008)	1	735-731 (980-975)	0.967	710-706 (947-941)	0.934	685-681 (914-908)	0.9
755-751 (1007-1001)	0.993	730-726 (974-968)	0.96	705-701 (940-935)	0.927	680-676 (907-901)	0.893

Convert inHg into mmHg → **mmHg = inHg x 25.4**
Convert inHg into mBar → **mBar = inHg x 33.864**



Wetland Studies and Solutions, Inc.®

Quality Assurance Project Plan (QAPP) For Biological Stream Monitoring

March 2010
Revised July 2013

A. Title and Approval Sheet

WETLAND STUDIES AND SOLUTIONS, INC.
QUALITY ASSURANCE PROJECT PLAN (QAPP)
FOR BIOLOGICAL MONITORING IN VIRGINIA
MARCH 2010,
REVISED JULY 2013

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Project QA Officer

B. Table of Contents

Sections

Exhibits

C. Distribution List

Name	Organization	Phone
Michael S. Rolband	Wetland Studies and Solutions, Inc.	703-679-5600

D. Project/Task Organization

Wetland Studies and Solutions, Inc. (WSSI) routinely conducts biological monitoring in Virginia for stream restoration and mitigation, as conditions of U.S. Army Corps of Engineer's Section 404 Permits and Virginia Water Protection Permits, for development submission requirements, and for wastewater discharge assessments, as well as to assess stream conditions. The data is typically submitted to Federal and State regulatory agencies for compliance with project requirements. WSSI also intends to share this data with the Virginia Department of Environmental Quality (DEQ) to aid in use determinations, 305(b) assessment, or 303(d) listing and delisting of impaired waters.

Below is an organization chart depicting the key WSSI personnel for biological stream monitoring projects as well as a brief description of their duties and qualifications.

Project Manager

Mark Headly

Biological Monitoring Coordinator/QAQC Officer/Laboratory Manager

Alison Robinson

Field Leaders/Laboratory Technicians

Benjamin N. Rosner, Jennifer D. Feese, Jennifer Van Houten, Beth Clements

Figure 1. Organizational chart for WSSI biological stream monitoring.

Project Manager

Mark W. Headly, PWS, PWD, LEED® AP

Mark Headly has over 35 years of experience in all aspects of environmental monitoring, assessment, and analysis with an emphasis on wetlands, floodplains, water quality, and watershed management. He serves as the project manager and point of contact for many of WSSI projects involving biological stream monitoring stream assessments, wetland delineation, permitting, mitigation design, as well as local resource protection issues, including Chesapeake Bay Preservation Act compliance. Mr. Headly is an expert in the regulatory programs of the U.S. Army Corps of Engineers (COE), Environmental Protection Agency (EPA), and state agencies in Virginia and Maryland, as well as local government water quality and resource protection initiatives.

As Executive Vice President responsible for WSSI's Environmental Services Division, Mr. Headly provides oversight and detailed review of all stream assessments, perennial flow determinations, wetland delineations, and wetland permitting. He is the project manager for the Northern Virginia Stream Restoration Bank, Phase I and Loudoun County Wetlands and Stream Bank, Phase II Biological Monitoring studies. Mr. Headly also served on the Loudoun County Strategic Watershed Solutions Project which led to the development of Loudoun County's Comprehensive Watershed Management Plan.

Biological Monitoring Coordinator/QAQC Officer/Laboratory Manager

Alison Robinson, WPIT, CT

Alison Robinson has more than five years of experience working in wetland and stream ecosystems, both in the Piedmont, Coastal Plain and in the Valley and Ridge of Virginia. She has conducted biological monitoring as a private consultant as well as in an academic setting. She has participated in and organized the biological monitoring of over 50,000 linear feet of stream in Northern Virginia over the past 4 years, using the U.S. EPA's Rapid Bioassessment Protocols, the Stream Condition Index for Virginia Non-coastal Streams and the Coastal Plain Macroinvertebrate Index. She also participates in the sorting and identification of the collected samples. She has assessed over 100,000 linear feet of streams in Northern Virginia utilizing the COE, Norfolk District and the Virginia Department of Environmental Quality's (DEQ) Unified Stream Methodology. She has also conducted stream assessments, using the stream evaluation methods developed by the North Carolina Division of Water Quality (NCDWQ) and the Fairfax County Department of Public Works and Environmental Services (DPWES) methods.

Ms. Robinson is a Certified Level I (Family-level) Taxonomists for All Taxa under the North American Benthological Society Taxonomic Certification Program (NABS TCP, now known as the Society of Freshwater Science). She is also a NABS TCP Family Level Test Supervisor for Virginia and a Certified Wetland Professional in Training. She is certified by the Maryland Department of Natural Resources to conduct macroinvertebrate sampling in Maryland under the Maryland Biological Stream Survey. She has also taught several benthic macroinvertebrate continuing education courses for WSSI employees.

Ms. Robinson is the biological monitoring coordinator at WSSI. She provides oversight and quality control for all aspects of biological monitoring projects at WSSI.

Field Leaders/Laboratory Technicians

Benjamin N. Rosner, PWS, PWD, CT, CE

Benjamin Rosner has over ten years of experience working in the environmental consulting business with WSSI. Mr. Rosner's primary responsibilities include performing biological stream assessments (DEQ biomonitoring method), stream flow determinations (Fairfax County DPWES method and NCDWQ method), benthic macroinvertebrate sampling and identification, conducting Resource Protection Area determination studies in accordance with local Chesapeake Bay Ordinances, site reconnaissance, wetland delineations, natural resource inventories, existing vegetation studies, endangered and threatened species searches and habitat evaluations, tree stand evaluations, wetland mitigation monitoring, conducting site visits with regulatory staff, preparing plans and permit applications to meet federal, state, and local regulatory requirements, and preparing documentation reports and exhibits. Mr. Rosner is a Certified Level I (Family-level) Taxonomists for All Taxa under the NABS TCP as well as a Certified Ecologist through the Ecological Society of America, a Virginia Certified Professional Wetland Delineator, and a Certified Professional Wetland Scientist.

Jennifer D. Feese, PWS, PWD, CT

Jennifer Feese has over eight years of experience in environmental consulting, specializing in wetlands and water resource management, for both the private and public sectors. Ms. Feese's experience at WSSI includes performing stream assessments (Fairfax County DPWES method, NCDWQ method, and the DEQ biomonitoring method), benthic macroinvertebrate sampling, conducting Resource Protection Area and Perennial Flow Determination studies in accordance with local Chesapeake Bay Ordinances, conducting site reconnaissance; wetland delineations; accompanying representatives from regulatory agencies on site visits to obtain Jurisdictional Determinations and wetland permits; and preparing documentation reports and exhibits. Ms. Feese is a Certified Level I (Family-level) Taxonomists for All Taxa under the NABS TCP as well as a Virginia Certified Professional Wetland Delineator, and a Certified Professional Wetland Scientist.

Jennifer Van Houten, PWS, PWD, CT, CE, LEED®AP

Jennifer Van Houten has over fifteen years of experience in environmental consulting with a specialization in water resource and wetlands management for both the private and public sectors. She is responsible for performing biological stream assessments (DEQ biomonitoring method), stream flow determinations (Fairfax County DPWES method and NCDWQ method), benthic macroinvertebrate sampling and identification, conducting Resource Protection Area determination studies in accordance with local Chesapeake Bay Ordinances, on-site wetlands reconnaissance, field delineations, COE Jurisdictional Determination field reviews, annual created wetlands and wetlands bank monitoring, COE and DEQ permit application preparation, wetlands delineation reports and sketches preparation. During her full-time tenure at WSSI, she has worked on more than 350 projects and 20 created wetlands sites. Mrs. Van Houten is a Certified Level I (Family-level) Taxonomists for All Taxa under the NABS TCP as well as a Virginia Certified Professional Wetland Delineator, a Certified Professional Wetland Scientist, and a Certified Ecologist through the Ecological Society of America.

Beth Clements, PWS, CT

Beth Clements has over seven years of experience in environmental consulting. She is responsible for biological stream monitoring, benthic macroinvertebrate sampling and identification, biological stream assessments (DEQ biomonitoring method), stream flow determinations (Fairfax County DPWES method and NCDWQ method), wetlands reconnaissance, field delineations, USCOE Jurisdictional Determination field reviews for wetland delineations, annual created wetlands and wetlands bank monitoring, COE and DEQ permit application preparation, wetlands delineation report and sketch preparations, Resource Protection Area (RPA) plan preparation, endangered and threatened species habitat evaluations and rare species/community assessment, and rare plant species searches. She is a Certified Level I (Family-level) Taxonomist for All Taxa under the NABS TCP and a Certified Professional Wetland Scientist. She is also certified by the Maryland Department of Natural Resources to conduct macroinvertebrate sampling in Maryland under the Maryland Biological Stream Survey.

E. Problem Definition/Project Background

WSSI routinely conducts biological monitoring in Virginia for stream mitigation, as conditions of waters of the U.S. and Virginia Water Protection Permits, for development submission requirements, and for wastewater discharge assessments as well as to assess current stream conditions. The data is typically submitted to Federal and State regulatory agencies for compliance with project requirements. WSSI would like to also submit this data to the DEQ's Freshwater Biological Monitoring Program for use determinations, 305(b) assessment, or 303(d) listing and delisting of impaired waters.

F. Project/Task Descriptions

WSSI conducts biomonitoring in both coastal and non-coastal physiographic provinces of Virginia, and biomonitoring methods often vary depending on physiographic provinces. Biomonitoring project timelines often also vary between projects, depending on project requirements. WSSI uses either the spring (March 1 through May 31) or fall (September

1 through November 30) index periods for sampling, depending on the project, and many of WSSI's projects are required to be completed by November 30 of each monitoring year. Benthic macroinvertebrate samples are not collected during periods of excessively high or low flows or within two weeks of a scouring flow event.

Benthic Macroinvertebrate Sampling

WSSI uses two methods for sampling benthic macroinvertebrates: the single habitat sampling approach and the multihabitat sampling approach. These methods are discussed in detail in WSSI's Standard Operating Procedures for Biological Monitoring of Streams in Virginia (Exhibit 1).

The single habitat sampling approach is used typically in high gradient streams (i.e., non-coastal streams), where cobble riffles are present and there is an ample area to sample at least one (1) square meter of the substrate. Exhibit 1 includes procedures for single habitat benthic macroinvertebrate sampling.

The multihabitat sampling method is typically used in low gradient streams (i.e., coastal non-tidal streams) where no riffles are present or the riffles are too small and/or too few to sample one (1) square meter of substrate. Exhibit 1 includes procedures for multi-habitat benthic macroinvertebrate sampling.

Benthic macroinvertebrate data in non-coastal streams is used to calculate the Virginia Stream Condition Index (VSCI)[1]. The VSCI is a multi-metric Index of Biotic Integrity used to assess the condition of non-coastal streams in Virginia. The VSCI uses seven biotic metrics and one biotic index. The VSCI is calculated by taking the weighted average of the individual metric (and index) scores. Each reach is then assigned a narrative rating according to the calculated VSCI, where "Excellent" is >73, "Good" is 60-72, "Stress" is 43-59, and "Severe Stress" is <42.

Benthic macroinvertebrate data in coastal non-tidal streams is used to calculate the Coastal Plain Macroinvertebrate Index (CPMI)[2]. The CMPI uses four biotic metrics and one biotic index. The CPMI is calculated by adding the weighted metric (and index) scores. Each reach is then assigned a narrative rating according to the calculated CPMI, where "Excellent" is 24-30, "Good" is 16-22, "Stress" is 6-14, and "Severe Stress" is 0-4.

[1] *Tetra Tech, Inc. 2003. A Stream Condition Index for Virginia Non-Coastal Streams. Tetra Tech, Inc. Owings Mills, Maryland. Prepared for Virginia Department of Environmental Quality, Richmond, Virginia.*

[2] *Maxted, J.R., M.T. Barbour, J. Gerritsen, V. Poretti, N. Primrose, A. Silvia, D. Penrose, and R. Renfrow. 2000. Assessment framework for mid-Atlantic coastal plain streams using benthic macroinvertebrates. J. N. Am. Benthol. Soc., 19(1):128-144.*

Stream Habitat Assessment

Habitat assessments are conducted at each biomonitoring reach. WSSI uses two methods for assessing stream habitat depending on stream gradient: habitat assessment for high gradient streams and habitat assessment for low gradient streams. Habitat conditions are assessed by qualitatively rating ten habitat parameters. Each reach is then assigned a narrative rating according to the total habitat score, where "Optimal" is 160-200, "Sub-optimal" is 159-107, "Marginal" is 106-54, and "Poor" is 0- 53. Exhibit 1 includes procedures for stream habitat assessment.

Water Chemistry Assessment

In-situ water quality parameters (dissolved oxygen, pH, temperature, and conductivity) are measured within each reach with a YSI Multi Probe System (MPS) field instrument. If further tests need to be conducted, samples will be sent out to a Virginia Environmental Laboratory Accreditation Program (VELAP) certified lab for testing.

G. Measurement Quality Objectives

To accurately and precisely assess the condition of streams while conducting biological stream assessments, WSSI has implemented several measures to ensure data quality, which are discussed below.

Data Precision, Accuracy, Measurement Range, Representativeness, Comparability, and Completeness

When conducting water chemistry analyses, WSSI tests for dissolved oxygen, pH, temperature, and conductivity. Table 1, below lists the Matrix, Measurement Range, and Accuracy of each water chemistry parameter.

Table 1: Matrix Measurement Range, and Accuracy of Water Quality Parameters

Parameter	Matrix	Measurement Range	Accuracy
Temperature	Water	-5 to 45ºC	±0.15 ºC
Dissolved Oxygen	Water	0 to 50 mg/L	0 to 20 mg/L: ±2% of reading or 0.2 mg/L; whichever is greater
Conductivity	Water	0 to 200 mS/cm	±0.5% of reading or ±0.001 mS/cm; whichever is greater – 4 meter cable
pH	Water	0 to 14 units	±0.2 units

WSSI staff are highly qualified to sample and identify macroinvertebrates to the family and genus-levels, to conduct stream habitat assessments, and to conduct water chemistry analyses. Highly trained and certified staff, as well as the use of standard operating procedures including quality assurance/quality control measures (Exhibit 1) ensure data quality when conducting biological stream assessments. WSSI staff certifications are included in Exhibit 2. A list of training classes is included below in Section H below.

The above practices and qualifications ensure the representativeness, comparability, and completeness of WSSI's monitoring data.

H. Training Requirements and Certification

All sampling, laboratory work, and data analysis are performed or supervised by the Coordinator/QAQC Officer/Laboratory Manager and Field Leaders /Laboratory Technicians. All benthic taxonomic identifications are performed by staff that has obtained a certification from the NABS TCP.

WSSI staff are highly trained in benthic macroinvertebrate sampling and identification and hold numerous taxonomic certifications through the NABS TCP, including the Biological Monitoring Coordinator/QAQC Officer/Laboratory Manager and all of the Field Leaders/Laboratory Technicians. WSSI has also hosted in-house trainings for benthic macroinvertebrate sampling and identification for numerous WSSI staff. Staff also attend annual sampling and identification refresher training courses and are required to become re-certified upon the expiration of their NABS TCP certification. A copy of each staff certificate is included in Exhibit 2. WSSI is also a NABS TCP Level I Approved Testing Center in Virginia. Below is a list of benthic macroinvertebrate training and other additional relevant training that WSSI staff has attended.

- Maryland Biological Stream Survey Spring Sampling Training, Maryland Department of Natural Resources, Carroll County, MD.
- Freshwater Mussel Identification, Association of Mid-Atlantic Aquatic Biologist Workshop, Cacapon, WV.
- Plecoptera Identification, Association of Mid-Atlantic Aquatic Biologist Workshop, Cacapon, WV.
- Applied Fluvial Geomorphology (Level I), Dave Rosgen/Wildland Hydrology, Shepherdstown, WV.
- River Morphology & Applications (Level II), Dave Rosgen/Wildland Hydrology, Gainesville, VA.
- "Calculating the Stream Condition Index for Use in Non-Coastal Streams of Virginia", WSSI, Gainesville, VA
- "Family-level Benthic Macroinvertebrate Training for Level I NABS Certification" , WSSI, Gainesville, VA
- "Ecology and Identification of Freshwater Macroinvertebrates in Wetlands", WSSI, Gainesville, VA
- Biological Monitoring of Stream Restoration, USFWS Conservation Science and Policy Training, Shepherdstown, WV
- Surface Water ID and Training Course, Atkins, Raleigh, NC

I. Documentation and Records

Benthic macroinvertebrate, stream habitat, and water chemistry data is collected in the field and entered onto standard data sheets included in Appendix B and Appendix C of Exhibit 1. Laboratory data is also entered onto standard data sheets (Appendix D of Exhibit 1). All data is then entered into either a Microsoft Excel spreadsheet or an Ecological Data Application System (EDAS). Reports are completed by the submission date required by the project. The samples and data reports are then archived by project.

J. Sampling Process Design

The sampling process design is outlined in the Standard Operating Procedures for Biological Monitoring of Streams in Virginia (Exhibit 1). WSSI uses a targeted sampling approach for biomonitoring projects. The number of sampling sites for a given project is based on project requirements (i.e., one 300-foot reach per 2,000 linear feet of stream restoration). Prior to conducting the fieldwork, a desktop and field reconnaissance is conducted to establish assessment reach locations. Relevant background information is reviewed including detailed site topography (when available), USGS quadrangle maps, National Wetlands Inventory maps, soils maps, and aerial photograph(s). This information is used to help geographically locate the streams on the site and establish potential sampling reach locations within representative streams. A field reconnaissance is conducted to establish exact reach locations. All streams are evaluated in the field to determine if they flow long enough in the year to sample. Streams with ephemeral flow are eliminated as candidate streams for sampling. Streams with intermittent flow are assessed on a case-by-case basis. Where possible, sampling reaches are 300 linear feet in length, located at least 300 feet upstream of any road or bridge crossing and do not have any major tributary streams flowing into the reach.

K. Sampling Method Requirements

Exhibit 1 includes sampling methods for the biological monitoring.

L. Sampling Handling and Custody Procedures

Qualified personnel (i.e., trained and certified) will be responsible for the sample collection, preservation, labeling, transport, and storage of benthic macroinvertebrate, stream habitat, and water chemistry data. No special custody requirements of samples are required.

M. Analytical Methods Requirements

Exhibit 1 includes procedures for collecting benthic macroinvertebrate, habitat, and water chemistry data.

N. Quality Control Requirements

Accuracy – WSSI's Measurement Quality Objective (MQO) for taxonomic precision is a Percent Taxonomic Disagreement (PTD) value of ≤ 10%. PTDs are calculated for 10% of samples taken annually from each staff. Samples are re-identified by the Project QA Officer to ensure accuracy. WSSI staff participates in continuing education courses to ensure that accuracy does not fall.

Sorting Efficiency- WSSI staff involved in laboratory sub-sampling of samples must first demonstrate the ability to remove ≥ 90% of the specimens per grid. For detailed sub-sampling procedures and QA/QC, (see Exhibit 1, Section A.d.xiv).
The QA/QC Officer/Biological Monitoring Coordinator also conducts annual audits to ensure that the proper procedures are being followed.

O. Instrument/Equipment Testing, Inspection, and Maintenance Requirements

All instruments and equipment are routinely checked prior to fieldwork to ensure its properly functioning. Equipment that is malfunctioning is required to be fixed or replaced prior to conducting fieldwork. Exhibit 3 includes information on maintenance of water chemistry sampling equipment.

P. Instrument Calibration and Frequency

Exhibit 3 includes procedures for calibrating water chemistry sampling equipment.

Q. Inspection/Acceptance Requirements for Supplies

All instruments and equipment are routinely checked prior to fieldwork to ensure its functioning properly. Equipment that is malfunctioning is required to be fixed or replaced prior to conducting fieldwork. Exhibit 3 includes information on maintenance of water chemistry sampling equipment.

R. Data Acquisition Requirements

Prior to conducting biological monitoring fieldwork, relevant background information is reviewed including a waters of the U.S. delineation (if available), detailed site topography (when available), USGS quadrangle maps, National Wetlands Inventory maps, soils maps, aerial photograph(s), DEQ water monitoring data, and local monitoring data such as Save Our Streams. This information helps geographically locate the streams on the site, establish potential sampling reach locations, and understand the water quality in the vicinity of the reach.

S. Data Management

See Section I.

T. Assessments and Response Actions

Assessment methods are described in Section F and in the standard operating procedures are described in Exhibit 1. The results of the assessments indicate the condition of the study reaches.

U. Reports

Reports are completed by the submission date required by the project and typically include the following:

- A narrative describing background information about the site, methods, results, discussion, conclusions, works cited, and limitations.
- An exhibit with Benthic Macroinvertebrate Laboratory Bench Sheets for each reach.
- An exhibit with upstream and downstream photographs of streams investigated during the sampling fieldwork.
- An exhibit with Field Data Sheets for each reach.
- A summary table showing metric and index scores for each reach.
- A summary table showing habitat assessment scores for each reach.
- A biological stream assessment map depicting the location of sampling reaches and photographs.

V. Data Review, Validation, and Verification

All field and laboratory data is reviewed, verified, and validated by the Field Leader, QA Officer, and Project Manager to ensure data has been compiled according to WSSI's standard operating procedures.

W. Validation and Verification Methods

Data review, verification, and validation will be performed using self-assessment and peer and management review. Any errors detected will be rectified by editing incorrect database entries, resampling, or excluding questionable data. On a yearly basis, sorting efficiency of sub-sampling macroinvertebrates are QA/QC'd by experienced personnel who will check all sorted quadrates from the first three samples processed by a sorter to ensure that all organisms were removed.

X. Reconciliation with Data Quality Objectives (DQO)

All data collected by WSSI is reviewed on an ongoing basis for accuracy, precision, and completeness. If data quality does not meet the appropriate specifications, data will be discarded and resampling may occur.

Exhibit 1

Standard Operating Procedures for Biological Stream Monitoring in Virginia

Wetland Studies and Solutions, Inc.®

STANDARD OPERATING PROCEDURES FOR BIOLOGICAL MONITORING OF STREAMS IN VIRGINIA

March 2010

Revised July 2013

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Appendices

A. Standard Operating Procedures for Conducting Biological Stream Assessments in Non-coastal Physiographic Province Streams:

a. *Reconnaissance*- Prior to conducting the biological stream assessment fieldwork, a desktop and field reconnaissance should be conducted to establish assessment reach locations.

   i. *Desktop Reconnaissance* - Relevant background information should be reviewed including a waters of the U.S. delineation (if available), site topography, USGS quadrangle map, National Wetlands Inventory map, soils map, and aerial photograph(s). This information should help geographically locate the streams on the site and establish potential sampling reach locations at representative streams.

   ii. *Field Reconnaissance* – A field reconnaissance should be conducted to establish reach locations. All streams should be evaluated in the field to determine if they flow long enough in the year to sample during the sampling index period[1]. Streams with ephemeral flows will be eliminated as candidate streams for sampling. Streams with intermittent flows will be assessed as candidate streams for sampling on a case by case basis. Where possible, sampling reaches should be 300 linear feet in length, located at least 300-feet upstream of any road or bridge crossing and should not have any major tributary streams flowing into the reach.

b. *Benthic Macroinvertebrate Field Procedures* – Biological assessment fieldwork should be conducted during the spring (March 1 through May 31) or fall (September 1 through November 30) index periods. Although sampling can be conducted during either of the two sampling periods, sampling should be conducted during the same index period if sampling is to be conducted over multiple years to assure consistency. <u>Appendix A</u> is an equipment list of field and laboratory supplies for conducting biological stream assessments using benthic macroinvertebrates.

   i. Walk the entire reach and sketch the approximate location of the sampling reach on a field map. Mark potential sampling areas on the field map and take an upstream and downstream photograph depicting each reach. The photographs should be taken within the reach from the center of the stream and depicting the habitat sampled. Mark the approximate location of each photograph on the field map.

   ii. Starting at the downstream end of the reach and moving upstream, sample the representative habitat throughout the reach. Sampling is conducted by holding the D-frame net on the bottom of the stream and kicking and rubbing the substrate (i.e., cobbles, root wads, woody debris) to agitate and dislodge organisms.

      1. For the single habitat method, a total of 2 square meters (m^2) of stream substrate will be sampled. These samples will occur only in riffles and runs. A single kick consists of disturbing the substrate upstream of the D-frame net by kicking with the feet and/or by using the hands to dislodge the

[1] *The spring index period occurs from March 1 through May 31. The fall index period occurs from September 1 through November 30.*

cobble/boulder for 30 seconds – 1 ½ minutes. For example six kicks disturbing a 1/3 of a m^2 above the D-frame net or 12 kicks disturbing a 1/6 of a m^2 of above the D-frame net should be used to sample a total of $2m^2$, at 30 seconds – 1 ½ minutes per kick net sample.

2. For the multihabitat method, 20 jabs, each 1 meter (m) in length will be sampled. Samples will be taken in stable and productive habitat, sampled downstream to upstream. Different types of habitat should be sampled in rough proportion to their frequency within the sampling reach. A single jab will consist of a jab into a productive habitat for 1 linear meter, followed by 2-3 sweeps of the same area to collect organisms for 20 seconds-1 ½ minutes per jab/sweep/kick.

iii. Samples should be cleaned and transferred to the sieve bucket at least every few kicks/jabs, more often if necessary, to prevent clogging of the net and the loss of organisms. Do not let the net become so clogged with debris that it results in the diversion of water around the net rather than through the net. If clogging occurs, discard the sample in the net and redo that portion of the sample in a different location.

iv. As the sample is added to the sieve bucket, it should be further washed to remove fines. Mix the sample by hand while sieving, remove large debris from the sample after rinsing and inspecting of organisms; place any organisms back into the sieve bucket. Do not attempt to inspect small debris. Try to wash the sample as gently as possible to prevent damage to the organisms.

v. Place a sample label (<u>Figure 1</u>), filled out in pencil, in a sample container(s) and label the lid with the same information as the sample label with a permanent marker. Transfer the sample from the sieve bucket the pre-labeled sample container(s) and preserve in 90 percent isopropyl alcohol. Fill the sample container with approximately one and a half times the amount of alcohol as needed to cover the sample. Forceps may be needed to remove organisms from the sieve screen and dip net. Field samples are then taken to the WSSI lab for sorting and identification.

WSSI BENTHIC SAMPLE

PROJECT/JOB# ______________________________
STATION ___________________________________
DATE ____________ TIME _________________
GEAR ____________ SAMPLE SIZE ____________
COLLECTORS _________________________________
LOG NUMBER _________________________________
REMARKS ___________________________________
____

Figure 1. WSSI benthic sample label.

c. *Habitat Characterization Field Procedures*– Habitat characterization should be conducted during the biological assessment fieldwork. Habitat conditions should be assessed following the Rapid Bioassessment Protocols for habitat and using the Benthic Macroinvertebrate and Habitat Data Sheet- High Gradient Habitat Data Sheet (Appendix B). Ten habitat parameters, including Epifaunal Substrate/Available Cover, Embeddedness, Velocity/Depth Regime, Sediment Deposition, Channel Flow Status, Channel Alteration, Frequency of Riffles, Bank Stability, Vegetation Protection, and Riparian Vegetative Zone Width are qualitatively rated, where the best possible score equals 200. Below are descriptions of the habitat parameters for high gradient streams.

  i. Epifaunal substrate/available cover includes the relative quantity and variety of natural structures in the stream, such as fallen trees, logs, branches, cobble and large rocks, and undercut banks that are available to fish and macroinvertebrates for refugia, spawning/nursery activities, or feeding. A wide variety of submerged structures in the stream provide aquatic organisms with many living spaces; the more living spaces in a stream, the more types of organisms the stream can support.

  ii. Embeddedness refers to the extent to which rocks (gravel, cobble and boulders) are surrounded by, covered or sunken into the silt, sand, or mud of the stream bottom. Generally, as rocks become embedded, fewer living spaces are available to macroinvertebrates and fish for shelter, spawning and egg incubation. This parameter is assessed primarily in the riffles, if present. To estimate the percent of embeddedness, observe the amount of silt or finer sediments surrounding the rocks. If kicking does not dislodge the rocks or cobbles, they may be greatly embedded. It may be useful to lift a few rocks and observe how much of the rock (e.g., ½, ⅓) is darker due to anoxic reaction to the inorganic surface.

  iii. Velocity/Depth regime is important to the maintenance of healthy aquatic communities. Fast water increases the amount of dissolved oxygen in the water, keeps pools from being filled with sediment, and helps food items like leaves, twigs, and algae move more quickly through the aquatic system. Slow water provides spawning areas for fish and shelters macroinvertebrates that might be washed downstream in higher stream velocities. Similarly, shallow water tends to be more easily aerated (*i.e.*, hold more oxygen), but deeper water stays cooler longer. Thus the best stream habitat will include all of the following velocity/depth combinations, and can maintain a wide variety of organisms.

    a. slow (<0.3 m/sec), shallow (<0.5 m)
    b. slow, deep
    c. fast, deep
    d. fast, shallow

  iv. Sediment deposition is a measure of the amount of sediment that has been deposited in the stream channel and the changes to the stream bottom that have occurred as a result of the deposition. Excessive levels of sediment deposition create an unstable and continually changing environment that is unsuitable for many aquatic organisms. Sediments are naturally deposited in areas where flow is obstructed. These deposits can lead to the formation of islands, shoals, or point bars (sediments that build up in the stream, usually at the beginning of a meander) or can result in the complete filling of pools. To determine whether or not these sediment deposits are new, look for vegetation growing on them; new sediments will not yet have been colonized by vegetation.

v. Channel flow status determines the percent of the channel that is filled with water. The flow status will change as the channel enlarges or as flow decreases as a result of dams and other obstructions, diversions for irrigation, or drought. When water does not cover much of the streambed, less living area is available for aquatic organisms. Assess the wetted width of the stream in relation to the location of the lower bank.

vi. Channel alteration is basically a measure of large-scale anthropogenic changes in the shape of the stream channel. Many streams in urban and agricultural areas have been straightened, deepened (e.g. dredged), or diverted into concrete channels, often for flood control purposes. Such streams have far fewer natural habitats for fish, macroinvertebrates, and plants than do naturally meandering streams. Channel alteration is present when the stream runs through a concrete channel; artificial embankments, riprap, and other forms of artificial bank stabilization or structures are present; combined sewer overflows (CSOs) pipes are present; and the stream is of uniform depth due to dredging. Signs that indicate the occurrence of dredging include straightened, deepened, and otherwise uniform stream channels, and the removal of streamside vegetation to provide dredging equipment access to the stream.

vii. Frequency of riffles (or bends) is a way to measure the heterogeneity occurring in a stream. Because riffles are a good source of high-quality habitat and faunal diversity, an increase in the frequency of riffles provides for greater diversity of the stream community. In streams where riffles are uncommon, a measure of the frequency of bends can be used as a measure of meandering or sinuosity, which also provides for a diverse habitat and fauna. Additionally, streams with a high degree of sinuosity are better suited to handle storm surges through absorption of energy by bends as well as providing refugia for fauna during storm events.

viii. Bank stability measures erosion potential and whether the stream banks are eroded. Steep banks are more likely to collapse and suffer from erosion than are gently sloping banks and are therefore considered to have high erosion potential. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil.

ix. Vegetative protection measures the amount of the stream bank that is covered by natural (*i.e.*, growing wild and not recently planted) vegetation. The root systems of plants growing on stream banks help hold soil in place, reducing erosion. Vegetation on banks provides shade for fish and macroinvertebrates, and serves as a food source by dropping leaves and other organic matter into the stream. Ideally, a variety of vegetation should be present, including trees, shrubs, and grasses. Vegetative disruption may occur when the grasses and plants on the streambanks are mowed or grazed upon, or the trees and shrubs are cut back or cleared.

x. Riparian vegetative zone width is defined as the width of natural vegetation from the edge of the stream bank. The riparian vegetative zone is a buffer zone to pollutants entering a stream from runoff; it also controls erosion and provides stream habitat and nutrient input into the stream. A wide, relatively undisturbed riparian vegetative zone reflects a healthy stream system; narrow, disturbed riparian zones occur when roads, parking lots, fields, lawns and other artificially cultivated areas, bare soil, rocks, or buildings are near the stream bank. The presence of "old fields" (*i.e.*, previously developed agricultural fields allowed to convert to natural conditions) should rate higher than fields in continuous or periodic use.

d. *Benthic Macroinvertebrate Laboratory Procedures* – Laboratory samples are to be sorted, sub-sampled, and identified to the lowest taxonomic level possible or to the level required by the individual project. Use the following procedures:

i. Remove the lid from the sample container and pull out the internal sample label (save the sample label – it will need to be returned to the sample container with the archived portion of the sample that does not get processed). Record sample collection information on the Benthic Macroinvertebrate Bench Sheet (Appendix D). Header information required includes job name/WSSI #, station ID, stream name, collectors, date sampled, sorter, date sorted, number of grids subsorted, number of insects subsorted, taxonomist, date identified, and total number of organisms identified.

ii. Fill out applicable information on the bench sheet (i.e. stream name, sorter, date sorted).

iii. Transfer the contents of the container to a 500-micron mesh sieve and gently wash off the preservative in a sink with cold water, gently rubbing any large debris (i.e. leaves, sticks, rocks) over the sieve to dislodge invertebrates and remove the debris from the sample.

iv. Transfer the sample material to the gridded sub-sampling tray (Figure 2) and spread out evenly.

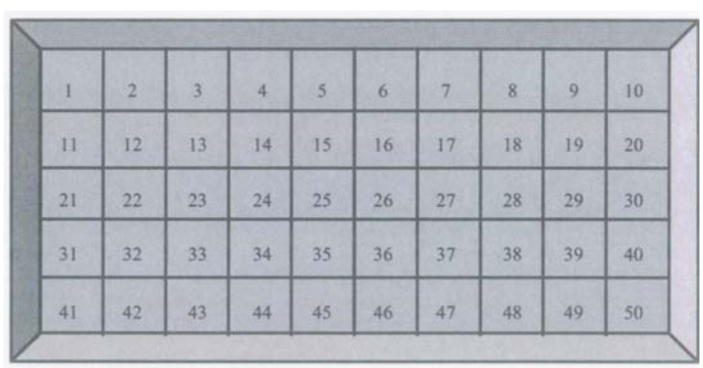

Figure 2. Gridded sub-sampling tray

v. Use a random number generator (e.g. random number table, cup with random numbers) to select a grid to process. Remove all the material from that grid and place the removed material into a separate petri dish

   1. An organism belongs to the grid containing its head. If it is not possible to determine the location of the head (*i.e.*, for worms), the organism is considered to be in the grid containing most of its body. If the head of an organism lies on the line between two grids, all organisms on the top of a grid and those on the right side of a grid belong in that grid, and are picked with that grid.

vi. Using a dissecting microscope, sort through the entire contents of each chosen cell and place any organisms with a head in a container with 70% isopropyl alcohol. Record the number of organisms found in each cell on the bench sheet.

   1. If more than 30-45 organisms are selected from the first grid, use your best professional judgment with regards to whether or not you should subsample (see Table 1). If subsampling skip to step A.d.x., if not continue with step A.d.viii.

vii. Continue selecting and processing randomly selected cells until 110 organisms +/- 10% (99-121) are counted. Each grid begun must be picked to completion; that is, even if the target is reached halfway through a grid, finish the entire grid. Each grid must be QAQC'ed by the Biological Monitoring Coordinator/QAQC Officer/Laboratory Manager or a Field Leader/Laboratory Technician when the sorted is finished with it to ensure no organisms were missed.

viii. If the last grid being processed results in more than 121 organisms (i.e., 10% above target number), evenly redistribute all of the organisms (without detritus) in a 25 grid tray. Use a random numbers table and counting backwards, from your total count, remove organisms from selected grid (s) (remember to remove ALL organisms in selected grid) until you are left with your target count of 110 organisms within 10% (99-121) remaining in the tray. The organisms that are removed may be discarded and the organisms that are remaining in your tray are your benthic sample to be identified.

ix. Do not remove or count empty snail or bivalve shells, pupae, specimens of surface-dwelling or strict water column arthropod taxa (e.g., Collembola, Veliidae, Gerridae, Notonectidae, Corixidae, Cladocera, or Copepoda), or incidentally-collected terrestrial taxa. Also do not count fragments such as legs, antennae, gills, or wings. For Oligochaeta, attempt to remove and count only whole organisms and fragments that include the head; do not count fragments that do not include the head.

x. Processing of high density samples:

   1. If more than 30 organisms are found within the first cell, use your best professional judgment to determine if you need to subsample. If subsampling is warranted then record the number of the sampled cell and the number of

insects found on the bench sheet and then discard all of the organisms picked from the first cell.

2. Using the table below, determine the number of cells to be removed from the sample based on the number of organisms found in the first cell. Use the random number table or cup to determine the cells to be removed and used as the subsample. An example of removal would be the following; when removing 15, 20, or 25 grids you should be able to remove 3, 4, or 5 columns from the box. For example if you are to remove 15 grids, choose 3 random numbers (i.e. 3, 28, 35) and remove columns 3, 8, and 5. If you are to remove 10 grids, choose 5 numbers (i.e. 2, 45, 17, 28, and 49) and remove grids next to one another. For example, grids 2 and 3 as well as 45 and 46, etc. Place the selected removed grids in the sorting tray and set aside. Place the remaining sample back in the original sample bucket.

    a. If a column picked for subsampling contains the 1st cell (that has already been picked) then discard that number and pick again. If the cell number immediately precedes the 1st cell picked then pick the cell before it (i.e. if your first cell was 8 and 7 was picked as a subsample cell, then pick 6 and 7 to get the correct number of cells to subsample).

Organisms per grid in original sample	Remove & keep following number of grids	Predicted number of organisms per grid	Predicted number of grids to reach 110	Multiplier for recording total number of grids picked
30-45	25	15-25.5	5-7	0.5
46-55	20	18.4-22	5-6	0.4
56-75	15	16.8-22.5	5-7	0.3
76-110	10	15.2-22	5-7	0.2
111-230	5	11.1-22	5-10	0.1
231-315	4	18.48-25.2	6-4	0.08

Table 1. Subsample reduction table.

3. Completely mix the selected grids in the tray. If the first grid has more than 30 organisms, use your best professional judgment, with regards to whether or not you should re-subsample, and then go back to step A.d.vii.

xi. Once subsampling is complete, transfer the contents of the gridded tray back to the original sample bucket. Put the original sample label back into the sample bucket and fill the bucket with 70% isopropyl alcohol. Archive the bucket in the lab for potential future reference.

xii. Identify all organisms in the subsample to the lowest taxonomic level applicable, or to the level required by the project and record on the Benthic Macroinvertebrate Bench Sheet. Place individuals from each taxa into a labeled shell vial, fill with 70%

isopropyl alcohol, plug the opening with a small amount of cotton, and store all shell vials into a labeled jar (Figure 1) for each reach.

xiii. Quality Assurance/Quality Control- Because it can be difficult to detect the organisms in stream samples (due to inexperience, detritus, etc.), only persons who have received instruction by senior biology staff familiar with processing benthic samples can perform a quality control (QC) check. These QC checks must be performed immediately following sorting of each grid. Therefore, a laboratory staff member qualified to perform QC checks must be present anytime samples are processed by another individual.

xiv. Qualification to be able to QAQC samples will only occur when sorters are consistent in achieving ≥ 90% sorting efficiency after at least five samples have been checked.

The QC checker will calculate sorting efficiency for each sample (See Figure 3 for formula). If sorting efficiency for each of the first five consecutive samples is ≥ 90% for a particular individual, this individual is considered "experienced" and can serve as a QC checker. In the event that an individual fails to achieve ≥ 90% sorting efficiency, they will be required to sort an additional five samples in order to continue to monitor their sorting efficiency. However, if they show marked improvement in their sorting efficiency prior to completion of the next five samples, whereby they acquire the ≥ 90% sorting efficiency, the QC checker may, at his/her discretion, consider this individual to be "experienced." Sorting efficiency should not be calculated for samples processed by more than one individual.

$$\text{\#organisms originally sorted} \div \left(\text{\#organisms recovered by checker} + \text{\#organisms originally sorted}\right) \times 100 = \text{\% sorting efficiency}$$

Figure 3. QA/QC formula for calculating sorting efficiency.

xv. Quality control checks should also be conducted as for sample identification. The procedure should be similar as the procedure described above for sorting efficiency.

xvi. Appendix E is a list of taxonomic references for benthic macroinvertebrate identification. Appendix F is an identification guide to common stream benthic macroinvertebrates of Virginia. Appendix G is an identification guide to freshwater mussels of Northern Virginia.

e. *Benthic Macroinvertebrate Data Entry/Analysis* – Calculating the Stream Condition Index for Virginia Non-Coastal Streams (SCI)

i. Benthic macroinvertebrate data should be entered into a Microsoft Excel spreadsheet or EDAS database to calculate the SCI for Virginia Non-Coastal Streams for each stream reach. This spreadsheet and EDAS database can be found at the following file path: K:\ENV Scientists\Templates\Reports\Benthics.

ii. Once benthic macroinvertebrate data is entered into spreadsheet, several benthic metrics will be automatically calculated, including Percent Ephemeroptera, Percent Plecoptera + Trichoptera (Excluding Hydropsychidae), Percent Scrapers, Percent Chironomidae, and Hilsenhoff Biotic Index. Other metrics including Total Taxa, EPT Taxa, and Percent Top Two Dominant will have to be manually calculated. Appendix H defines these seven metrics and index.

iii. Once the metrics are calculated, the SCI numerical score will automatically be calculated. Appendix H describes the calculations for the SCI. Use the numeric thresholds in Table 2 to determine the SCI narrative score.

Table 2. Scoring Thresholds for Determining the Narrative Score for the Virginia Stream Condition Index

NUMERICAL SCORE	NARRATIVE SCORE
<42	Severe Stress
43-59	Stress
60-72	Good
>73	Excellent

f. *Habitat Data Entry/Analysis*- Determining habitat quality

i. Habitat data should be entered into a Microsoft Excel spreadsheet or EDAS to determine the overall habitat quality of each reach. This spreadsheet can be found at the following file path: K:\ENV Scientists\Templates\ Reports\Benthics.

ii. Overall habitat quality is determined by totaling the habitat score for each reach. Use Table 3 to determine the overall habitat quality of each reach.

Table 3. Scoring Thresholds for Determining the Overall Habitat Quality

TOTAL HABITAT SCORE	NARRATIVE SCORE
160-200	Optimal
159-107	Suboptimal
106-54	Marginal
0-53	Poor

g. *Report* – The report is intended to discuss the overall condition of the established stream reaches on the study site. The report should include the following:

i. A narrative describing background information about the site, methods, results, discussion, conclusions, works cited, and limitations.

ii. An exhibit with Benthic Macroinvertebrate Laboratory Bench Sheets for each reach.

iii. An exhibit with photographs of streams investigated during the sampling fieldwork.

iv. An exhibit with the Benthic Macroinvertebrate and Habitat Field Data Sheets for each reach.

v. A summary table showing the metric and index scores for each reach.

vi. A summary table showing habitat assessment scores for each reach.

vii. A biological stream assessment map depicting the location of sampling reaches and photographs.

B. Standard Operating Procedures for Conducting Biological Stream Assessments in Coastal Plain Physiographical Province Streams:

a. *Reconnaissance*- See Section A.a. for reconnaissance procedures.

b. *Benthic Macroinvertebrate Field Procedures*- Biological assessment fieldwork should be conducted during the spring (March 1 through May 31) or fall (September 1 through November 30) index periods. Although sampling can be conducted during either of the two sampling periods, sampling should be conducted at the same index period if sampling is to be conducted over multiple years to assure consistency. Appendix A is an equipment list of field and laboratory supplies for conducting biological stream assessments using benthic macroinvertebrates.

i. Benthic macroinvertebrates occur in a variety of stream habitats in the coastal plain, and different types of organisms use different habitat types within these types of streams. For this reason, benthic macroinvertebrates should be collected from the best available habitats (including gravel and cobble riffles, submerged snags, stick/leaf packs, undercut banks, submerged aquatic vegetation, and root mats) within each reach.

ii. Walk the entire reach and sketch the approximate location of the sampling reach on a field map. Mark potential sampling habitats on the field map and take an upstream and downstream photograph depicting each reach. The photographs should be taken within the reach from the center of the stream and depicting the habitat sampled. Mark the approximate location of each photograph on the field map.

iii. Sampling is conducted from downstream to upstream by either jabbing the D-frame net into submerged snags, sticks/leaf packs, undercut banks, submerged vegetation, and root mats, or kicking riffle substrates upslope of the net. A single jab consists of forcefully thrusting the net into the habitat for 3 linear feet. A single kick consists of gently kicking the riffle substrate 3 linear feet upstream of the net. A total of twenty jabs/kicks should be taken at best available habitat throughout the entire reach.

iv. See Section A.b.iii. – A.b.v.

c. *Habitat Characterization Field Procedures* – Habitat characterization should be conducted during the biological assessment fieldwork. Habitat conditions should be assessed following the Rapid Bioassessment Protocols for habitat and using the WSSI Benthic Macroinvertebrate Habitat Assessment Field Data Sheet- Low Gradient Habitat Data Sheet (Appendix E). Ten habitat parameters, including Epifaunal Substrate/Available Cover, Pool Substrate Characterization, Pool Variability, Sediment Deposition, Channel Flow Status, Channel Alteration, Channel Sinuosity, Bank Stability, Vegetative Protection, and Riparian Vegetative Zone Width, are qualitatively rated, where the best possible score equals 200. Below are descriptions of the habitat parameters for low gradient streams.

i. Epifaunal substrate/available cover includes the relative quantity and variety of natural structures in the stream, such as fallen trees, logs, branches, cobble and large rocks, and undercut banks, that are available to fish and macroinvertebrates for refugia, spawning/nursery activities, or feeding. A wide variety of submerged structures in the stream provide aquatic organisms with many living spaces; the more living spaces in a stream, the more types of organisms the stream can support.

ii. Pool substrate characterization refers to the type and condition of bottom substrates found in pools. Firmer sediment types (*e.g.*, gravel, sand) and rooted aquatic plants support a wider array of organisms than pools dominated by mud or bedrock and with little or no plants. Additionally, streams with a variety of substrate types will support far more types of organisms than streams with uniform pool substrates.

iii. Pool variability rates the overall mixture of pool types found in streams according to size and depth. Streams with many pool types support a wider variety of organisms than streams with fewer pool types. Thus the best stream habitat will include all of the following pool types, and can maintain a wider variety of aquatic species.

a) large (>half cross-section of stream) –shallow (<1.0 m)
b) large-deep
c) small-shallow
d) small-deep

iv. Sediment deposition is a measure of the amount of sediment that has been deposited in the stream channel and the changes to the stream bottom that have occurred as a result of the deposition. Excessive levels of sediment deposition create an unstable and continually changing environment that is unsuitable for many aquatic organisms. Sediments are naturally deposited in areas where the stream flow is reduced, such as pools and bends, or where flow is obstructed. These deposits can lead to the formation of islands, shoals, or point bars (sediments that build up in the stream, usually at the beginning of a meander) or can result in the complete filling of pools.

To determine whether or not these sediment deposits are new, look for vegetation growing on them: new sediments will not yet have been colonized by vegetation.

v. Channel flow status determines the percent of the channel that is filled with water. The flow status will change as the channel enlarges or as flow decreases as a result of dams and other obstructions, diversions for irrigation, or drought. When water does not cover much of the streambed, less living area is available for aquatic organisms. Assess the wetted width of the stream in relation to the location of the lower bank.

vi. Channel alteration is basically a measure of large-scale anthropogenic changes in the shape of the stream channel. Many streams in urban and agricultural areas have been straightened, deepened (e.g., dredged), or diverted into concrete channels, often for flood control purposes. Such streams have far fewer natural habitats for fish, macroinvertebrates, and plants that do naturally meandering streams. Channel alteration is present when the stream runs through a concrete channel; artificial embankments, riprap, and other forms of artificial bank stabilization or structures are present; the stream is very straight for significant distances; dams, bridges and flow-altering structures, such as combined sewer overflow (CSOs) pipes are present; the stream is of uniform depth due to dredging. Signs that indicate the occurrence of dredging include straightened, deepened, and otherwise uniform stream channels, and the removal of streamside vegetation to provide dredging equipment access to the stream.

vii. Channel sinuosity is a way to measure the meandering or sinuosity occurring in a stream. A stream with a high degree sinuosity provides for a more diverse habitat and fauna than a stream with a low degree of sinuosity. Additionally; streams with a high degree of sinuosity are better suited to handle storm surges through absorption of energy by bends as well as providing refugia for fauna during storm events.

viii. Bank stability measures erosion potential and whether the stream banks are eroded. Steep banks are more likely to collapse and suffer from erosion that are gently sloping banks and are therefore considered to have a high erosion potential. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil.

ix. Vegetative protection measures the amount of the stream bank that is covered by natural vegetation (*i.e.*, growing wild and not recently planted) which helps hold soil in place, reducing erosion. Vegetation on banks provides shade for fish and macroinvertebrates, and serves as a food source by dropping leaves and other organic matter into the stream. Ideally, a variety of vegetation should be present, including trees, shrubs , and grasses. Vegetative disruption may occur when the grasses and plants on the streambanks are mowed or grazed upon, or the trees and shrubs are out back or cleared.

x. Riparian vegetative zone width is defined as the width of natural vegetation from the edge of the stream bank. The riparian vegetative zone is a buffer zone to pollutants entering a stream from runoff; it also controls erosion and provides stream habitat and nutrient input into the stream. A wide, relatively undisturbed riparian vegetative zone reflects a healthy stream system; narrow, disturbed riparian zones occur when roads, parking lots, fields, lawns and other artificially cultivated areas, bare soil, rocks, or buildings are near the stream bank. The presence of "old fields" (*i.e.*, previously developed agricultural fields allowed to convert to natural conditions) should rate higher than fields in continuous or periodic use.

d. *Benthic Macroinvertebrate Laboratory Procedures* – See Section A.d for benthic macroinvertebrate laboratory procedures.

e. *Benthic Macroinvertebrate Data entry/Analysis* – Calculating the Coastal Plain Macroinvertebrate Index (CPMI)

i. Benthic macroinvertebrate data should be entered into a Microsoft Excel spreadsheet or EDAS database to calculate the CPMI for Virginia Coastal Streams for each stream reach. This spreadsheet and EDAS database can be found at the following file path: K:\ENV Scientists\Templates\Reports\Benthics.

ii. Once benthic macroinvertebrate data is entered into spreadsheet, several benthic metrics will be automatically calculated, including % Ephemeroptera, Hilsenhoff Biotic Index, and % Clingers. Other metrics including Total Taxa and EPT Taxa will have to be manually calculated. Appendix H defines these four metrics and index.

iii. Once the metrics are calculated, the CPMI numerical score will automatically be calculated. Appendix H describes the calculations for the CPMI. Use the numeric thresholds in Table 4 to determine the CPMI narrative score.

Table 4. Scoring Thresholds for Determining the Narrative Score for the Coastal Plain Macroinvertebrate Index

NUMERICAL SCORE	NARRATIVE SCORE
24-30	Excellent
16-22	Good
6-14	Stress
0-4	Severe Stress

f. *Habitat Data entry/Analysis*- See Section A.f. for habitat data entry/analysis procedures.

g. *Report* – See Section A.g for report procedures.

Literature Cited

United States Environmental Protection Agency. 1997. Field and laboratory methods for macroinvertebrate and habitat assessment of low-gradient nontidal streams. Mid-Atlantic Coastal Streams Workgroup, Environmental Services Division, Region 3, Wheeling, W.V.

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APPENDIX A:

EQUIPMENT LIST OF FIELD AND LABORATORY SUPPLIES FOR CONDUCTING BIOLOGICAL STREAM ASSESSMENTS USING BENTHIC MACROINVERTEBRATES

Appendix A. Equipment list of field and laboratory supplies for conducting biological stream assessments using benthic macroinvertebrates.

Field Equipment

1. D-framed dip net
2. Boots (chest waders, hipboots, or knee boots)
3. Flagging
4. Sieve Bucket, with 500 micron mesh
5. 5-gallon bucket
6. Squirt bottle
7. Preservative- 70-90% Isopropanol or Ethanol (2 pints per sample)
8. Sample containers, sample container labels (2 per reach)
9. Forceps
10. Pencils, sharpies
11. RBP protocols
12. Field datasheets
13. First aid kit
14. Camera
15. Maps
16. 300’ measuring tape

Laboratory Equipment

1. Dissecting microscope
2. Forceps
3. Preservative- Isopropanol or Ethanol
4. Vials/Jars
5. Laboratory bench sheets
6. Pencils, sharpies
7. Taxonomic references
8. Gridded Sub-sampling tray
9. Magnifier
10. 500 micron mesh sieve tray
11. Random number table or cup

<u>APPENDIX B</u>:

HIGH GRADIENT FIELD DATA SHEET

Wetland Studies and Solutions, Inc.®

Benthic Macroinvertebrate and Habitat Field Data Sheet - High Gradient

Station ID:		Ecoregion:		Land Use:	
Field Team:		Location:		Start time:	
Site:		Latitude:		Finish time:	
Date:		Longitude		Survey Reason:	

Stream Physiochemical Measurements

Instrument ID number:	________		pH:	________
Temperature:	________	°C	Conductivity:	________ uS/cm
Dissolved Oxygen:	________	mg/L	Did instrument pass all post-calibration checks?	________
			If NO- which parameter(s) failed and action taken:	________

Benthic Macroinvertebrate Collection

Method Used:			Single Habitat (Riffle)	________		Multi Habitat (Logs, Plants, etc.)		________
Riffle Quality:	Good	________	Marginal	________	Poor	________	None	________
Habitats Sampled:	Riffle	________	Rootwads/ Woody Debris	________	Banks	________	Vegetation	________
	# Jabs:	________		________		________		________

Weather Observations

Current Weather	Cloudy	________	Clear	________	Rain/Snow	________	Foggy	________
Recent Precipitation	Clear	________	Showers	________	Rain	________	Storms	________
Stream Flow	Low	________	Normal	________	Above Normal	________	Flood	________

Biological Observations

Periphyton	________	Salamanders	________	Other.... ________
Filamentous Algae	________	Warmwater Fish	________	0= Not observed
Submerged Macrophytes	________	Coldwater Fish	________	1= Sparse
Emergent Macrophytes	________	Beavers	________	2= Common to Abundant
Crayfish	________	Muskrats	________	3= Dominant-
Corbicula	________	Ducks/Geese	________	Abnormally high density where other taxa
unionidae	________	Snakes	________	are insignificant in relation to the dominant
Operculate Snails	________	Turtles	________	taxa. There can be situations where multiple
Non-operculate Snails		Frogs/Tadpoles		taxa are dominant such as algae and snails

High Gradient Habitat Data Sheet

Habitat Parameter	Condition Category				
	Optimal	Suboptimal	Marginal	Poor	Score
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble, or other stable habitat and at stage to allow full colonization potential (i.e. snags/logs that are not new fall and not transient).	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintainance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization.	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast shallow)(slow is <0.3m/s, deep is >0.5 m).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
4. Sediment Deposition	Little or no enlargement of islands or point bars and <5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	

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Benthic Macroinvertebrate and Habitat Field Data Sheet - High Gradient

Habitat Parameter	Condition Category				
	Optimal	**Suboptimal**	**Marginal**	**Poor**	**Score**
5. Channel Flow status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the availible channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the availible channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
6. Channel Alteration	Channelization or dredging absent or minimal; stream width normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging, may be present, but recent channelization is not present.	Channeliztion may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
7. Frequency of Riffles	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distances between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
8. Bank Stability (score each bank) Note: Determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.	
Score Left Bank	10 9	8 7 6	5 4 3	2 1 0	
Score Right Bank	10 9	8 7 6	5 4 3	2 1 0	
9. Vegetation Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetation disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.	
Score Left Bank	10 9	8 7 6	5 4 3	2 1 0	
Score Right Bank	10 9	8 7 6	5 4 3	2 1 0	
10. Riparian Vegetative Zone Width (score each banks riparian zone)	Width of riparian zone >18 meters; human activities (i.e. parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riperian zone <6 meters; little or no riparian vegetation due to human activities.	
Score Left Bank	10 9	8 7 6	5 4 3	2 1 0	
Score Right Bank	10 9	8 7 6	5 4 3	2 1 0	
		Total Score			0

Notes:

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APPENDIX C:

LOW GRADIENT FIELD DATA SHEET

Wetland Studies and Solutions, Inc.®

Benthic Macroinvertebrate and Habitat Field Data Sheet - Low Gradient

Station ID:		Ecoregion:		Land Use:	
Field Team:		Survey Reason:		Start time:	
Stream Name:		Location:		Finish time:	
Date:		Latitude:		Longitude	

Stream Physiochemical Measurements

Instrument ID number:			pH:		
Temperature:		°C	Conductivity:		mS/cm
Dissolved Oxygen:		mg/L	Did instrument pass all post-calibration checks?		
			If NO- which parameter(s) failed and action taken:		

Benthic Macroinvertebrate Collection

Method Used:	Single Habitat (Riffle)				Multi Habitat (Logs, Plants, etc.)			
Riffle Quality	Good		Marginal		Poor		None	
Habitats Sampled and # Jabs	Riffle		Snags		Banks		Vegetation	
Total area sampled (sq. m)								

Weather Observations

Current Weather	Cloudy		Clear		Rain/Snow		Foggy	
Recent Precipitation	Clear		Showers		Rain		Storms	
Stream Flow	Low		Normal		Above Normal		Flood	

Biological Observations

Periphyton		Salamanders		Other....
Filamentous Algae		Warmwater Fish		0= Not observed
Submerged Macrophytes		Coldwater Fish		1= Sparse
Emergent Macrophytes		Beavers		2= Common to Abundant
Crayfish		Muskrats		3= Dominant*
Corbicula		Ducks/Geese		
Unionidae		Snakes		
Operculate Snails		Turtles		
Non-operculate Snails		Frogs/Tadpoles		

*Abnormally high density where other taxa are insignificant in relation to the dominant taxa. There can be situations where multiple taxa are dominant such as algae and snails.

Notes

Low Gradient Habitat Data Sheet

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor	Score
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble, or other stable habitat and at stage to allow full colonization potential (i.e. snags/logs that are not new fall and not transient).	30-50% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization.	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation	Hare-pan clay or bedrock; no root mat or vegetation	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
3. Pool Variability	Even mix of large, shallow, large deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
4. Sediment Deposition	Little or no enlargement or islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	

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Benthic Macroinvertebrate and Habitat Field Data Sheet - Low Gradient

Habitat Parameter	Condition Category				
	Optimal	Suboptimal	Marginal	Poor	Score
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
6. Channel Alteration	Channelization or dredging absent or minimal; stream width normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging, may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note: Channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas).	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length <1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.	
Score	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.	
Score Left Bank	10 9	8 7 6	5 4 3	2 1 0	
Score Right Bank	10 9	8 7 6	5 4 3	2 1 0	
9. Vegetation Protection (score each bank) Note: Determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetation disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.	
Score Left Bank	10 9	8 7 6	5 4 3	2 1 0	
Score Right Bank	10 9	8 7 6	5 4 3	2 1 0	
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e. parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.	
Score Left Bank	10 9	8 7 6	5 4 3	2 1 0	
Score Right Bank	10 9	8 7 6	5 4 3	2 1 0	
Total Score					

Notes:

APPENDIX D:

WSSI BENTHIC MACROINVERTEBRATE BENCH SHEET

WSSI BENTHIC MACROINVERTEBRATE BENCH SHEET

Wetland Studies and Solutions, Inc.®

Job Name/#		Sample subsorted by:			
Station ID:		Date Subsorted:			
Stream Name:		# of Grids subsorted			
Date Sampled:		Total # of subsorted insects:		Total # identified:	
Sampling Method:		Sample Identified by:		Date Identified:	

Taxa Collected:

Porifera	Spongillidae	
Ostracoda	Unknown	
Flatworms	Tricladida	
	Planariidae	
Gastropoda	Unknown	
Limpets	Ancylidae	
Snails	Immature	
	Lymnaeidae	
	Physidae	
	Planorbidae	
	Hydrobiidae	
	Pleuroceridae	
	Viviparidae	
Bivalvia	Immature	
	Corbiculidae	
	Sphaeriidae	
	Unionidae	
Oligochaeta	Unknown	
Lumbriculida		
	Lumbriculidae	
Tubificida		
	Enchytraeidae	
	Naididae	
	Tubificidae	
Haplotaxida		
	Haplotaxidae	
Leeches	Hirudinea	
	Erpobdellidae	
	Glossiphoniidae	
	Hirudinidae	
	Pisciolidae	
Branchiobdellida	Branchiobdellidae	
Copepoda	Unknown	
Decapoda	Cambaridae	
	Portunidae	
Shrimp		
	Palaemonidae	
Isopoda		
	Asellidae	
Amphipoda		
	Crangonyctidae	
	Gammaridae	
	Talitridae	
Water Mites		
	Hydracarina	
Ephemeroptera	Early Instar and/or damaged	
	Acanthometropodidae	
	Ameletidae	
	Baetidae	
	Baetiscidae	
	Behningiidae	
	Caenidae	
	Ephemerellidae	
	Ephemeridae	
	Heptageniidae	
	Isonychiidae	
	Leptophlebiidae	
TOTAL:		0

	Metretopodidae	
	Neoephemeridae	
	Oligoneuridae	
	Psuedironidae	
	Polymitarcyidae	
	Potamanthidae	
	Siphlonuridae	
	Tricorythidae	
Zygoptera	Early Instar and/or damaged	
	Calopterygidae	
	Coenagrionidae	
	Lestidae	
	Protoneuridae	
Anisopteera	Early Instar and/or damaged	
	Aeshnidae	
	Cordulegastridae	
	Corduliidae	
	Gomphidae	
	Libellulidae	
	Macromiidae	
	Petaluridae	
	Cordullidae/Libelluidae	
Plecoptera	Early Instar and/or damaged	
	Capniidae	
	Chloroperlidae	
	Leuctridae	
	Nemouridae	
	Peltoperlidae	
	Perlidae	
	Perlodidae	
	Pteronarcyidae	
	Taeniopeterygidae	
Hemiptera	Early Instar and/or damaged	
	Belostomatidae	
	Corixidae	
	Gelastocoridae	
	Gerridae	
	Hebridae	
	Hydrometridae	
	Mesoveliidae	
	Naucoridae	
	Nepidae	
	Notonectidae	
	Veliidae	
	Pleidae	
Neuroptera		
	Sisyridae	
Megaloptera		
	Corydalidae	
	Sialidae	
Trichoptera	Early Instar and/or damaged	
	Branchycentridae	
	Calamoceratidae	
	Glossosomatidae	
	Goeridae	
	Heliicopsychidae	
	Hydropsychidae	
	Hydroptilida	
TOTAL:		0

	Lepidostomatidae	
	Leptoceridae	
	Limnephilidae	
	Molannidae	
	Odontoceridae	
	Philopotamidae	
	Phryganeidae	
	Polycentropodidae	
	Psychomyiidae	
	Ryacophilidae	
	Sericostomatidae	
	Uenoidae	
Lepidoptera	Early Instar and/or damaged	
	Pyralidae	
Coleoptera	Early Instar and/or damaged	
	Chrysomelidae	
	Curculionidae	
	Dryopidae	
	Dytiscidae	
	Elmidae	
	Gyrinidae	
	Haliplidae	
	Helodidae	
	Helophoridae	
	Hydraenidae	
	Hydrochidae	
	Hydrophilidae	
	Limnichidae	
	Noteridae	
	Psephenidae	
	Ptilodactylidae	
	Scirtidae	
Diptera	Early Instar and/or damaged	
	Athericidae	
	Blephariceridae	
	Canaceidae	
	Ceratopogonidae	
	Choaboridae	
	Chironomidae	
	Culicidae	
	Dixidae	
	Dolichopodidae	
	Epididae	
	Ephydridae	
	Muscidae	
	Nymphomyiidae	
	Pelecorhynchidae	
	Psychodidae	
	Ptychopteridae	
	Sciomyzidae	
	Simuliidae	
	Stratiomyidae	
	Syrphidae	
	Tabanidae	
	Tanyderidae	
	Thaumaleidae	
	Tipulidae	
TOTAL:		0

Sub-sample and Sample Reduction
(per SOP)

Organisms found in first grid= ____________ (Grid #____)

If <30 organisms found, contintute to table below.
If >30 organisms found, discard 1st grid, enter # of grids for sample reduction and continue to table below.

Sample Reduction? Y _______ N ____________ Number of Grids selected for ____________

Grid I.D. #	# of Organisms	Grid I.D. #	# of Organisms	Grid I.D. #	# of Organisms	Grid I.D. #	# of Organisms

Total organisms __________ Total Grids ____________

For sample reduction: ______________________ x ______________________ = ______________________

<u>IF</u> after picking, there are >121 organisms, then return picked sample to 15-30 grid tray and remove grids (per SOP) to reduce sample to 121 organisms or less. Record data below.

Total # of organisms retained= _______________
Grids removed to reduce sample to 121 organisms fewer= ____________

Percentage of grids retained for sample (to total grids) = ____________

______________________ x ______________________ = ______________________
(# of grids from original sample (A)) (% of grids retained) (final corrected # of grids from original sample)

<u>APPENDIX E</u>:

TAXONOMIC REFERENCES FOR BENTHIC MACROINVERTEBRATE IDENTIFICATION

Appendix E. Taxonomic references for benthic macroinvertebrate identification.

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< http://www.dep.state.fl.us/labs/cgi-bin/sbio/keys.asp >; you must scroll down to the listing for this manual, then click on the entry "Leeches.pdf"'; do not attempt a download if you are using a dial-up internet connection]. [good keys, information, for Floridian spccies that also have distributions elsewhere in North America]

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M. L. May. 2000. Dragonflies of North America. Scientfic Publishers, Gainesville, FL. 939 pp.

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Milligan, M.R. 1997. Identification manual for the aquatic Oligochaeta of Florida, Volume I. Freshwater oligochaetes. 187 pp. Florida Department of Environmental Protection, Tallahassee. [This manual is available free, as a pdf document that you can download from the Florida Department of Environmental Protection website, at: < http://www.dep.state.fl.us/labs/cgi-bin/sbio/keys.asp > Note: this identification manual was extensively based on the Brinkhurst (1986) guide, and then published one year before Kathman and Brinkhurst (1998), and thus significantly outdated; yet, the information presented in this manual, especially for the freshwater oligochaete fauna occurring in Florida, is still useful; many nomenclatural and systematic changes have occurred since this manual was published].

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Strayer, D. 1990. Aquatic Oligochaeta. Pages 373-397, In: B.L. Peckarsky, P.R. Fraissinet, M.A. Penton, and D.J. Conklin, Jr. (eds). Freshwater macroinvertebrates of northeastern North America. Comstock Publishing Associates, Ithaca, NY. xi + 442 pp. Paper softcover. ISBN 0-8014-9688-8.

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APPENDIX F:

IDENTIFICATION GUIDE TO COMMON STREAM BENTHIC MACROINVERTEBRATES OF VIRGINIA

APPENDIX F: IDENTIFICATION GUIDE TO COMMON STREAM BENTHIC MACROINVERTEBRATES OF VIRGINIA

INTRODUCTION

Scope of Key

Stream benthic macroinvertebrates are small stream-dwelling animals that do not have vertebrae and are visible with the naked eye. Because different types of benthic macroinvertebrates differ in their sensitivity to stream impacts, the composition of the benthic macroinvertebrate community in a stream can provide information about the relative health of the given watershed.

Stream benthic macroinvertebrates are complex in form and function. This guide was developed to help simplify benthic macroinvertebrate identification, introduce stream benthic macroinvertebrates to the regulated public and regulators, and facilitate the use of the benthic condition assessment parameter in the future for assessing stream impacts in Virginia.

This guide only covers the most common benthic macroinvertebrates found in Virginia. Most groups, or taxa, in this guide are keyed to the order level, with emphasis on those that are commonly collected in Virginia streams. Others are keyed to the phylum, class or family level. The taxonomic hierarchy used to classify animals is as follows:

Kingdom —> Phylum —> Class —> **Order** —> Family —>
Genus —> Species

Using the Key

This key is made up of sections called couplets or triplets. A couplet consists of two character choices, each of which leads you to a result. The result can either be an endpoint, or lead the user to another couplet or triplet. A triplet is similar to a couplet, but has three character choices, all of which can lead to an endpoint or another couplet or triplet. Endpoints are in bold and are the lowest taxonomic level in the key. Couplets and triplets are in paired and tripled numbers. The first character choice in a couplet or triplet is a number (e.g. 1). The second choice in a couplet or triplet is a number with a "prime" symbol attached (e.g. 1'). In a triplet, the third character choice is a number with a double-prime symbol attached (e.g. 1"). Following the number for each choice in a couplet is the location where the present couplet or triplet originated. This number is in parentheses. Additionally, a glossary of terms is provided on page 188.

HOW TO READ A COUPLET

If the organism is identified by this half [6 (3")] of couplet 6, then the organism is an adult beetle, order Coleoptera

Previous couplet

6 (3"). Body hard, beetle-like; hardened wingpads meet along centerline of back (Fig. 14)
…………………………..adult beetles, order **Coleoptera** (in part)

Endpoint (in bold)

Current couplet

Figure for first half of couplet 6.

Character description on figure.

Figure 14. Examples of different types of adult beetles (order Coleoptera).

Figure heading or first half of couplet 6.

Adult beetles vary considerably in shape; however, the body of all adult beetles is very hard. Beetles are facultative to most forms of environmental stress. Some species have very narrow environmental requirements and are found only in undisturbed areas.

Description of taxa described by endpoint

6' (3"). Body mostly soft, not beetle-like; wingpads, if present, are more soft (Fig. 15)…………….7

Figure for second half of couplet 6.

Figure 15. Examples of stream macroinvertebrates with non-beetle-like bodies.

If the organism is identified by this half [6' (3")], then proceed to couplet 7.

Figure heading for second half of couplet 6.

ACKNOWLEDGEMENTS

Matthew Rowe and Chris Luckett of the Maryland Department of the Environment (MDE), Dave Penrose of North Carolina State University, and Larry Butler and Diana Saccone of the Reston Association provided invaluable technical advice and editorial support for the Benthic Condition section of this Manual.

PHOTOGRAPH AND ILLUSTRATION CREDITS

The following websites were used to obtain photographs for this guide:

www.usa.ca, www.naturdetektive.de, www2.nrm.se, http://members.aol.com/Mkohl2/NAPleuroceridae.html, www.microscopy-uk.org.uk, www.benthos.org, www.inhs.uiuc.edu, www. bioweb.lu, www.dec.state.ny.us, www.bayern.de, www.cals.ncsu.edu, ww.delawarenaturesociety.org,www.utexas.edu, www.insects.tamu.edu, www.kulak.ac.be, www.cedarcreek.umn.edu, www.canadianbiodiversity, www.riverwatershed.org, www.zooex.baikal.ru, www.nps.gov, www.bugpeople.org, www.reflex.at/…/Tiere_im_Wasserzygoptera.htm, www.uci.net, www.dfg.ca.gov, www.info.wlu.ca, www.usask.ca, www.julia-nki.hu, www.shore.co.monmouth.nj.us, www.ittiofauna.org, www.umd.umich.edu, www.zooex.baikal.ru/ beetles/hydrophilidae.htm, www.ausrivas.canberra.edu.au, www.epa.gov

The following books were used to obtain illustrations for this guide:

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Voshell, Jr., Reese. 2002. *A Guide to Common Freshwater Invertebrates of North America .* The McDonald and Woodward Publishing Company.

KEY TO COMMON STREAM BENTHIC MACROINVERTEBRATES OF VIRGINIA (WITHOUT FIGURES)

1. With shell (Fig. 1)………………………………..……..…....................... 2
1'. Without shell (Fig. 2)……………………………..………….....……… 3

2 (1). Body enclosed by single shell (Fig. 3)
…………………………………………snails and limpets, class **Gastropoda**
2' (1). Body enclosed by two hinged shells (Fig. 4)
..…………………..…………..……clams and mussels, class **Bivalvia**

3 (1'). Body contains fewer than six legs (or leg-like appendages), or no legs; worm-like (Fig. 5)..…………….………………………...…………... 4
3' (1'). Body contains more than six legs (Fig. 6)…………….................. 5
3" (1'). Body contains six legs (Fig. 7)……...class Insecta (in part) ……. 6

4 (3). Body unsegmented, flattened; eyespots usually present. (Fig. 8)
……………………………………..…………flatworms, class **Turbellaria**
4' (3). Body segmented; no distinct head or appendages
(Fig. 9)……………..……………....….aquatic worms, phylum **Annelida**
4" (3). Body segmented, with a head (may be retracted
in body); most have leg-like appendages (pro-legs) (Fig. 10)
………………………..…true flies (larvae), class Insecta, order **Diptera**

5 (3'). Body with large carapace and pair of pincer-like
appendages (Fig. 11)…………………..….crayfish, family **Cambaridae**
5' (3'). Body without large carapace and pair of pincer-like appendages; flattened from top to bottom (Fig. 12)
…………………………………...………aquatic sowbugs, order **Isopoda**
5" (3'). Body without large carapace and pair of pincer-like appendages; flattened from side to side (Fig.13)……..….scuds, order **Amphipoda**

6 (3"). Body hard, beetle-like; hardened wingpads meet along centerline of back (Fig. 14)…………..adult beetles, order **Coleoptera** (in part)
6' (3"). Body mostly soft, not beetle-like; wingpads, if present, are more soft (Fig. 15)…...……………………………………..………………...………… 7

7 (6'). Head with rostrum ; first pair of legs may be larger than the rest (Fig. 16)………..…………………………true bugs, order **Hemiptera**
7' (6'). Head without rostrum; lower jaw of head with grasping append-age (Fig. 17)……………dragonflies and damselflies, order **Odonata**
7" (6'). Head not as above (Fig. 18)……………………….…………….. 8

Continue on next page →

8 (7”). End of body with two long tails (cerci) and no hooks; no gills on abdomen (Fig. 19)…………………………..stoneflies, order **Plecoptera**
8’ (7”). End of body with three (sometimes two) long tails (cerci) and no hooks; gills present on sides of abdomen
(Fig. 20)……………………...……….mayflies, order **Ephemeroptera**
8” (7”). End of body with hooks; if without hooks, then body ends in one slender filament **or** several short appendages **or** body flat and plate-like; larvae may make constructed case or net (Fig.20)……………..…..9

9 (8”). End of body with pair of hooks; most construct a case of various material including silk, sand, pebbles, or plant material, few are free living
(Fig. 21)……………………………..caddisflies, order **Trichoptera**
9’ (8”). End of body with 2 pairs of hooks, each on a pro-leg, or end of body with a single slender filament; conspicuous filaments on sides of abdomen
(Fig. 22); large opposing jaws
………………..fishflies, dobsonflies, and alderflies, order **Megaloptera**
9” (8”). End of body without pair of hooks, slender filament, or conspicuous filaments on sides of abdomen (except in whirligig beetle larvae, which have a pair of hooks on end of abdomen on a single pro-leg and filaments on sides of abdomen); body may be flat and plate-like
(Fig. 23) ……………...…………………..larval beetles, order **Coleoptera**

KEY TO COMMON STREAM BENTHIC MACROINVERTEBRATES OF VIRGINIA (WITH FIGURES)

1. With shell (Fig. 1)……………………………….……..……..... 2

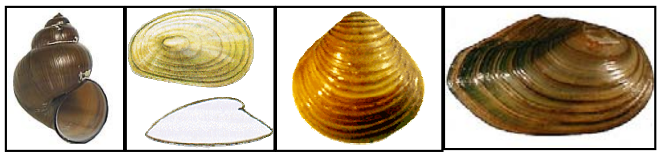

FIGURE 1:Examples of stream benthic macroinvertebrates with shells.

1'. Without shell (Fig. 2)……………………………..…......……… 3

FIGURE 2: Examples of stream benthic macroinvertebrates without shells.

2 (1). Body enclosed by single shell (Fig. 3)
…………………….……..snails and limpets, class **Gastropoda**

FIGURE 3: Examples of different types of snails (class Gastropoda).

Gastropods are freshwater macroinvertebrates consisting of a single shell, with a soft body inside. In most types, the shell is coiled, with the exception of the limpets, which have a flat cone-shaped shell with no coiling. Gastropods range from environmental stress tolerant to stress sensitive, depending on type.

2' (1). Body enclosed by two hinged shells (Fig. 4)
...……..…………...…………clams and mussels, class **Bivalvia**

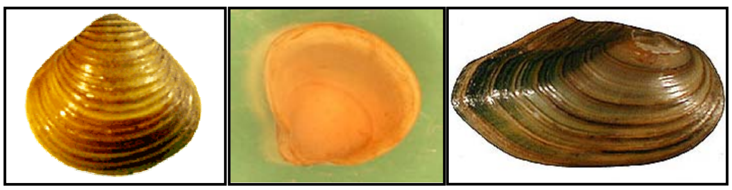

FIGURE 4: Examples of different types of bivalve (class Bivalvia).

Bivalves are freshwater macroinvertebrates consisting of two shells, with a soft body inside. Clams have somewhat rounded shells. Mussels have more oval-shaped shells. Clams are generally tolerant to environmental stress, whereas mussels are generally sensitive to environmental stress.

3 (1’). Body contains fewer than six legs (or leg-like appendages), or no legs; worm-like (Fig. 5) ………....……………..……………… 4

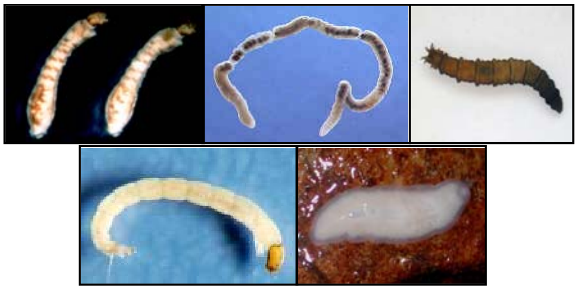

FIGURE 5: Examples of worm-like stream macroinvertebrates with fewer than six legs, or no legs.

3’ (1’). Body contains more than six legs (Fig. 6)……………..... 5

FIGURE 6: Examples of stream macroinvertebrates with more than six legs.

3” (1’). Body contains six legs (Fig. 7)
…………………………………….…class Insecta (in part), ….. 6

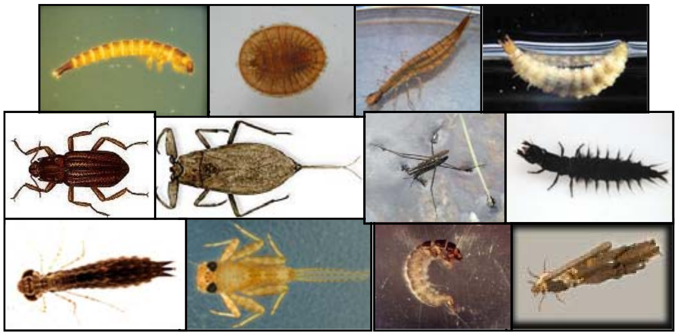

FIGURE 7: Examples of stream macroinvertebrates with six legs.

4 (3). Body unsegmented, flattened; eyespots usually present. (Fig. 8)……………………………flatworms, class **Turbellaria**

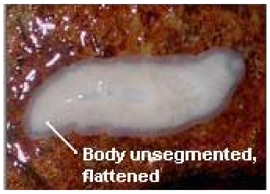

FIGURE 8: Example of a flatworm (class Turbellaria)

Flatworms are freshwater benthic macroinvertebrate worms that are unsegmented and flattened from top to bottom. Most are dark shades of gray, brown, or black. Most common kinds of flatworms are somewhat tolerant to environmental stress.

4' (3). Body segmented; no distinct head or appendages (Fig. 9)………………………………aquatic worms, phylum **Annelida**

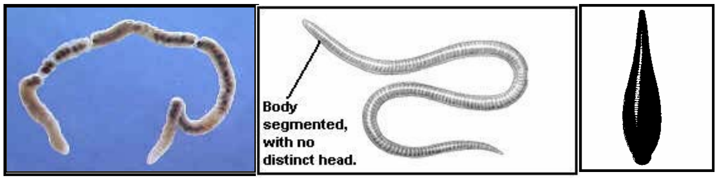

FIGURE 9: Examples of annelids (phylum Annelida).

Annelids are freshwater benthic macroinvertebrate worms that are segmented, cylindrical or flattened, and elongate. Leeches (subclass Hirudinea) have a sucker on the front and the rear. Oligochaetes (subclass Oligochaeta) lack any suckers. Oligochaetes

4" (3). Body segmented, with a head (may be retracted in body); most have leg-like appendages (pro-legs) (Fig. 10) …………………true flies (larvae), class Insecta, order **Diptera**

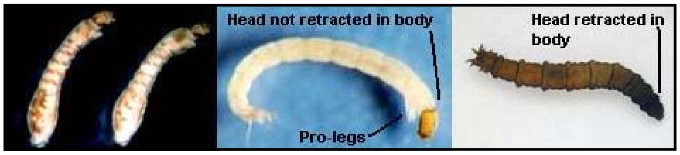

FIGURE 10: Example of dipteran larvae (class Diptera)

Dipteran larvae are worm-like freshwater benthic macroinvertebrate insects that are segmented, have a distinct head, and most have several fleshy appendages. A few types are very tolerant to environmental stress.

5 (3’). Body with large carapace and pair of pincer-like appendages (Fig. 11)……………..….crayfish, family **Cambaridae**

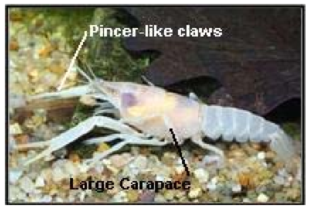

FIGURE 11: Example of a crayfish (family Cambaridae)

Crayfish are crustaceans with a large carapace and a pair of large pincer-like appendages. They are facultative to most forms of environmental stress.

5’ (3’). Body without large carapace and pair of pincer-like appendages; flattened from top to bottom (Fig. 12) ………………………..………aquatic sowbugs, order **Isopoda**

FIGURE 12: Example of an isopod (family Asellidae)

Isopods are crustaceans that are flattened from top to bottom. They are common in leaf-packs and in small-order streams. Asellidae is the only family of isopods in Virginia streams. Most types of aquatic isopods are tolerant to environmental stress.

5” (3’). Body without large carapace and pair of pincer-like appendages; flattened from side to side (Fig.13) ……………………………….…………..scuds, order **Amphipoda**

FIGURE 13: Example of scud (order Amphipoda)

Scuds are crustaceans that are flattened from side to side and shrimp-like in appearance. They are common in leaf-packs and in small-order streams. Scuds are facultative to most forms of environmental stress.

6 (3"). Body hard, beetle-like; hardened wingpads meet along centerline of back (Fig. 14) …………………………..adult beetles, order **Coleoptera** (in part)

FIGURE 14: Examples of different types of adult beetles (order Coleoptera).

Adult beetles vary considerably in shape; however, the body of all adult beetles is very hard. Beetles are facultative to most forms of environmental stress. Some species have very narrow environmental requirements and are found only in undisturbed areas.

6' (3"). Body mostly soft, not beetle-like; wingpads, if present, are more soft (Fig. 15)…...………7

FIGURE 15: Examples of stream macroinvertebrates with non-beetle-like bodies.

7 (6’). Head with rostrum ; first pair of legs may be larger than the rest (Fig. 16)………...…………true bugs, order **Hemiptera**

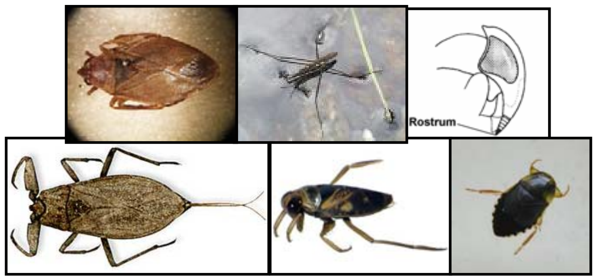

FIGURE 16: Examples of different types of hemipterans (order Hemiptera).

Hemipterans are considered true bugs, with piercing-sucking mouthparts. Several types have an enlarged first pair of legs. Since hemipterans do not depend on dissolved oxygen for respiration, some types can be found in very polluted environments.

7’ (6’). Head without rostrum; lower jaw of head with retractable grasping appendage (Fig. 17)
……………………dragonflies and damselflies, order **Odonata**

FIGURE 17: Examples of dragonflies and damselflies (order odonata), and grasping appendage.

Odonates are distinguished by the grasping appendage on the underside of their head. Dragonflies are genderally larger and more stout than damselflies. Additionally, damselflies have three flat, elongate paddle-like gills on the end of their body.

7” (6’). Head not as above (Fig. 18)……………………………..8

FIGURE 18: Stream macroinvertebrates without a grasping appendage and with non-piercing-sucking mouthparts.

8 (7”). End of body with two long tails (cerci) and no hooks; no gills on abdomen (Fig. 19)…..stoneflies, order **Plecoptera**

FIGURE 19: Examples of different types of stoneflies (order Plecoptera).

Stoneflies can be distinguished from other aquatic insects by their long thin antennae, which project in front of the head. They have two (never three) long filament-like tails on the end of their body. Additionally, many have gills on the underside of the thorax. Gills are never present on the abdomen. Stoneflies are the most pollution sensitive order in all of the aquatic insects.

8’ (7”). End of body with three (sometimes two) long tails (cerci) and no hooks; gills present on sides of abdomen (Fig. 20)……………………….mayflies, order **Ephemeroptera**

FIGURE 20: Examples of different types of mayflies (order Ephemeroptera).

Most mayflies are distinguished by having three filament-like tails on the end of their body. Gills are located laterally on the abdomen. Most species of mayflies are very sensitive to environmental stress.

8” (7”). End of body with hooks; if without hooks, then body ends in one slender filament **or** several short appendages **or** body flat and plate-like; larvae may make constructed case or net (Fig. 20)…………………………………………………………….. 9

FIGURE 21: Stream macroinvertebrates with bodies that end in hooks, a single filament, or several short appendages; some make constructed case or net.

9 (8”). End of body with pair of hooks; most construct a case of various material including silk, sand, pebbles, or plant material, few are free living (Fig. 21)
………………..…………………..caddisflies, order **Trichoptera**

FIGURE 22: Examples of different types of caddisflies (order Trichoptera).

Caddisflies are distinguished by having a pair of pro-legs at the end of their body, each with a single hook. Most have filament or branched gills on their abdomen. Many caddisflies construct a case or net out of various materials including silk, sand, pebbles, or plant material. Most species of caddisflies are very sensitive to environmental stress.

9’ (8”). End of body with 2 pairs of hooks, each on a pro-leg, or end of body with a single slender filament; conspicuous filaments on sides of abdomen (Fig. 22); large opposing jaws …… fishflies, dobsonflies, and alderflies, order **Megaloptera**

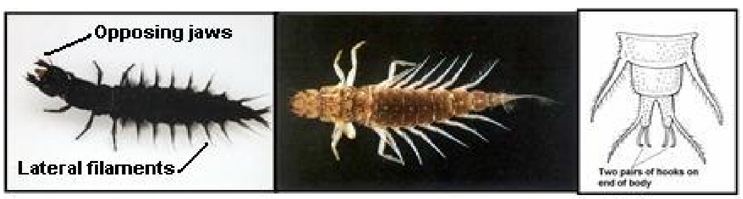

FIGURE 23: Examples of different types of megalopterans (order Megaloptera).

Most megalopterans are very large relative to other aquatic insect larvae. They have large opposing jaws and filament-like appendages on the sides of their abdomen. Most have a pair of hooks on the end of their body, with the exception to the alderflies, which have a single slender filament. Megalopterans are considered facultative to most environmental stress.

9" (8"). End of body without pair of hooks, slender filament, or conspicuous filaments on sides of abdomen (except in whirligig beetle larvae, which have a pair of hooks on end of abdomen on a single pro-leg and filaments on sides of abdomen); body may be flat and plate-like (Fig. 23)
………..…………..………..larval beetles, order **Coleoptera**

FIGURE 24: Examples of different types of beetle larvae (order Coleoptera).

Beetle larvae can be very difficult to distinguish from other aquatic insect larvae. Bodies of water beetle larvae are variable. Some have large sickle-like opposing jaws. Most do not have conspicuous filaments on the sides of their abdomen or a pair of hooks on the end of their body. Beetles are facultative to most forms of environmental stress. Some species have very narrow environmental requirements and are found only in undisturbed areas.

GLOSSARY OF TERMS

1. **Abdomen:** The third main division of the body in insects; behind the head and the thorax.
2. **Carapace:** Large, shield-like structure covering the front end of crayfish.
3. **Cerci:** Long, filament-like appendages extending from the abdomen of mayflies and stoneflies.
4. **Crustaceans:** The subphylum of arthropods that includes the isopods, scuds, crayfish, and shrimp in streams.
5. **Facultative:** Referring to stream benthic macroinvertebrates that occur in environments with conditions ranging from low to moderate levels of environmental stress.
6. **Lateral:** A feature located on the side of the body or other structure.
7. **Pro-legs:** A non-jointed appendage that serves for locomotion or attachment.
8. **Rostrum**: Structure on the head of hemipterans for piercing prey.
9. **Segmented:** Referring to distinct body regions or sections in annelid worms.
10. **Sensitive:** Usually found in nearly pristine environments; quickly eliminated with disturbance.
11. **Tolerant:** Referring to stream benthic macroinvertebrates that occur in disturbed environments.

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NOTES:

<u>APPENDIX G</u>:

IDENTIFICATION GUIDE TO FRESHWATER MUSSELS OF NORTHERN VIRGINIA

IDENTIFICATION GUIDE TO FRESHWATER MUSSELS AND CLAMS OF NORTHERN VIRGINIA

First Edition, December 2009
Prepared By Sean D. Sipple, CT, CE, PWS, PWD

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INTRODUCTION

Freshwater mussels and clams are in the Phlyum Mollusca and belong to the Class Bivalvia. Within Virginia, there are a wide variety of freshwater mussel and clam species, many of which are of Endangered, Threatened or Special Concern status at the State and/or Federal levels. Invasive freshwater bivalves from two families, Corbiculidae and Dreissenidae, also have been found in Virginia. The Asian clam, *Corbicula fluminea*, is widespread throughout Virginia. The zebra mussel, *Dreissena polymorpha*, has been documented in Virginia, but has not become established.

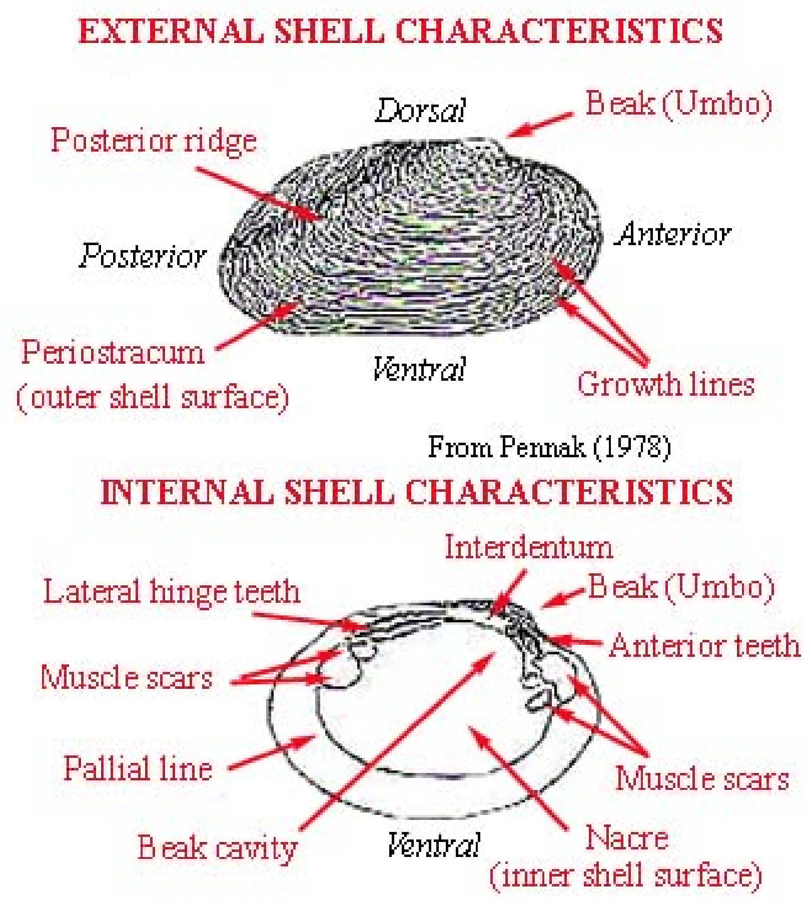
Freshwater bivalves can be found in permanent waterbodies in Virginia, but sometimes, can survive in temporary bodies such as intermittent streams, vernal pools, and oxbow lakes. However, mussels are not usually found in streams that dry for long periods of time.

Freshwater bivalves feed by filtering fine particulate organic matter, algae, and bacteria from the water column. Studies have shown that this filtering can improve water quality by removing excess nutrients and algae from the water.

Freshwater bivalves, especially mussels were historically much more abundant then they currently are. Factors including harvesting, sedimentation, toxins, and nutrients have lead to much of their decline in recent years. Sedimentation causes the gills of mussels to become clogged and they are also sensitive to pollutants such as heavy metals and ammonia from agricultural use.

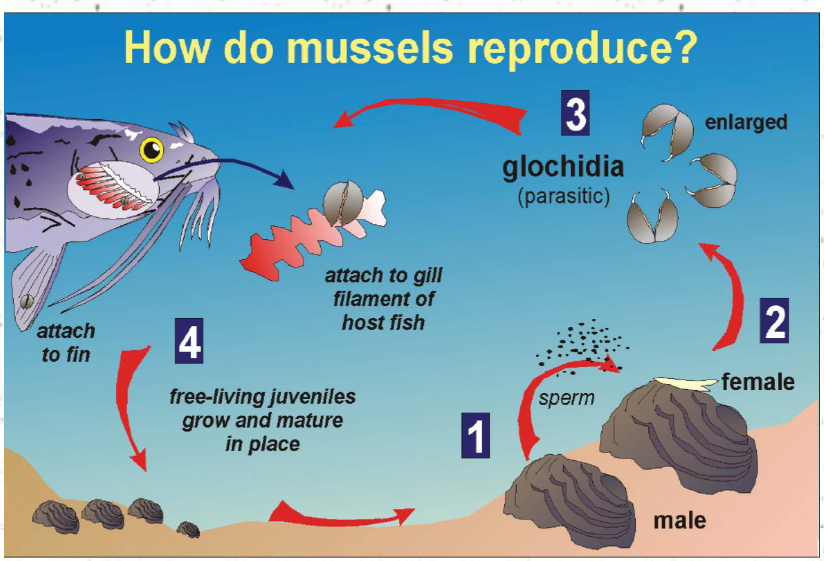
This field guide is intended to assist scientists with the identification of freshwater mussels and clams in the field. It covers most of the species found in the Atlantic Slope of Northern Virginia.

SHELL MORPHOLOGY



FRESHWATER MUSSEL LIFE CYCLE

Freshwater mussel reproduction begins when male mussels release sperm into the water column. The female mussels then take in the sperm as they filter the water. Upon fertilization, the female remains gravid for several weeks to several months. The larval mussels are called glochidia. Once released by the female, many of these glochidia must parasitize a fish or salamander host to complete development. Some species are able to develop without the use of a host. The use of a fish host allows mussels to disperse throughout a watershed.

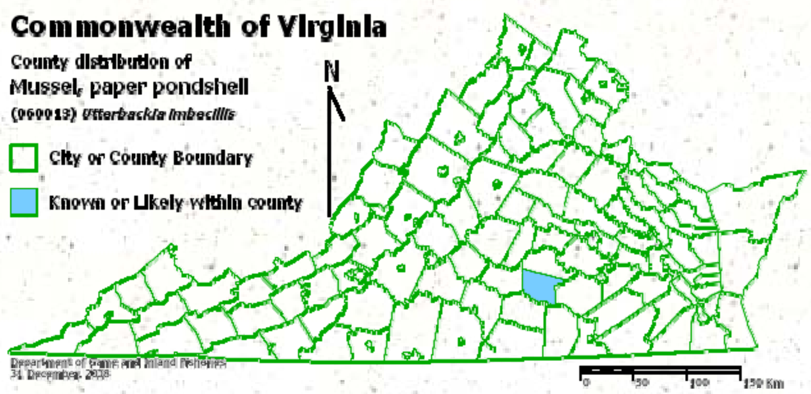


The paper pondshell is an introduced species, widespread and successful throughout central and southern North America, and now present in the Northeast region.

The shell is thin, oblong, and inflated. Juveniles, however, are greatly compressed. In especially favorable habitat, individuals may exceed 100 mm in length and become extremely inflated, almost circular in cross section. The Paper Pondshell lacks hinge teeth, and the umbos are flush with the hinge line. The periostracum is yellowish or greenish with numerous fine green rays. The nacre is bluish-white or silvery.

Habitat inlcudes ponds, lakes, and muddy-bottomed pools in rivers and streams.

Known fish hosts include *Ambloplites rupestris, Aplocheilus lineatus, Barbus semifasciolatus, Betta splendens, Brachydonia kerri, Colisa lalia, Etheostoma lepidum, Fundulus diaphanous, Gambusia affinus, Haplochromis venustus, Hemmigrammus erythrozonus, Lepomis cyanellus, Lepomis gibbosus, Lepomis gulosus, Lepomis macrochirus, Lepomis marginatus, Lepomis megalotis, Melanotaenia maccullochi, Melynnis argenteus, Micropterus salmoides Moenkhausia oligolepis, Pangio myers, Perca flavescens, Poecilia reticulate, Pomoxis nigromaculatus, Pseudotropheus zebra, Rasbora einthovenii, Semotrilus atromaculatus, Trichogaster trichopterus,* and *Xphophorus helleri.* Known amphibian hosts include *Ambystoma tigrinum, Rana catesbeiana, Rana pipens,* and *Xenopus laevis.*



UTTERBACKIA IMBECILLIS
PAPER PONDSHELL

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CLASS BIVALVIA-CLAMS AND MUSSELS

1. Shell asymmetrical, generally oblong (Fig. 1)…………….………..2

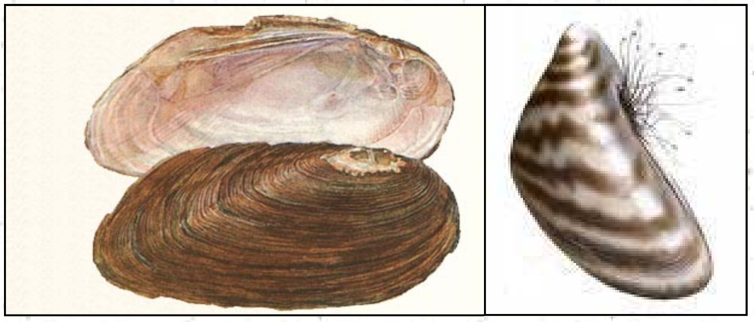


Fig. 1: Example of bivalves with asymmetrical and oblong shape.

1'. Shell more or less symmetrical, with lateral teeth on both sides of cardinal teeth (Fig. 2)……..…………………………..…….…...3

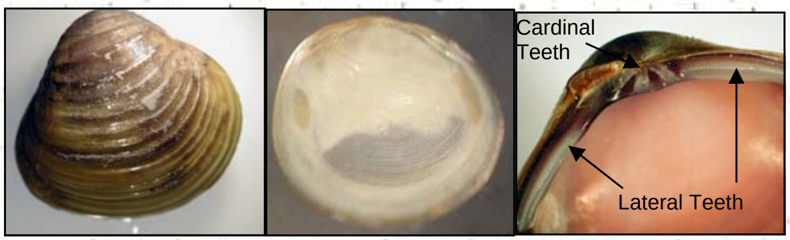
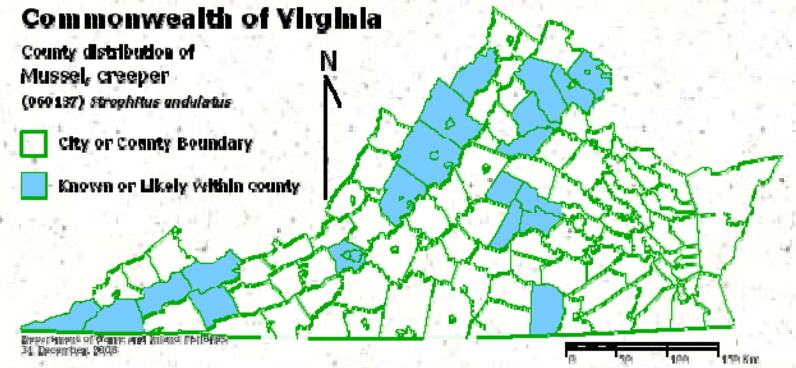


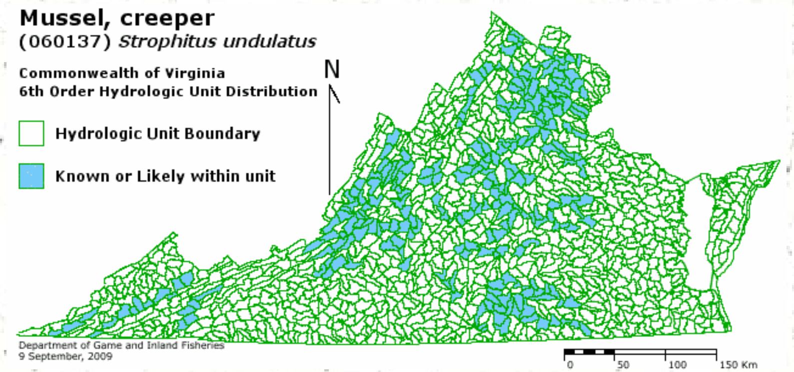
Fig. 2: Example of bivalve with symmetrical shape and lateral teeth on both sides of cardinal teeth.

The shell is elliptical, somewhat rhomboid, solid, compressed, and thin when young, moderately inflated and thick in mature and old individuals. Shell length is usually less than 110 mm. Lateral teeth are absent or suggested by a thickened hinge line. The periostracum is yellowish or greenish, marked by greenish, often wavy rays; old shells are dark brown or black and usually rayless. The nacre is white or bluish-white and iridescent around the margins.

Habitat includes slow water of all sizes, and lakes. Substrate includes silt, sand, gravel and mixes.

Known host species include *Ambloplites rupestris, Ameiurus melas, Ameiurus natalis, Campostoma anomalum, Cottus cognatus, Cubea inconstans, Etheostoma caeruleum, Etheostoma exile, Etheostoma flabellare, Etheostoma nigrum, Etheostoma olmstedi, Fundulus zebrinus, Ictaluns punctatus, Lepomis cyanellus, Lepomis gibbosus, Lepomis macrochirus, Lota lota, Luxilis cornutus, Micropterus dolomica, Micropterus salmoides, Nocomis micropogon, Notropis hudsonius, Notropis lundibundis, Oncorhynchus mykiss, Perca flavescens, Percina caprodes, Percina maculate, Percina phoxocephala, Pimephales notatus, Pimephales promelas, Pomoxis annularis, Pomoxis nigromaculatus, Rhinichthys atratulus, Rhinichthys cartaractae Salvelinus fontinalis, Semotilus atromaculatus, Stizostedion vitreum,* and *Umbra limi.* Known amphibian hosts include *Notophthalmus vidridescens.* Also, no host required.





STROPHITUS UNDULATUS
CREEPER

- **Moderately thick shelled**
- **Lacks thickening along antero-ventral margin**
- **Kidney shaped**
- **Usually small-medium size (< 8 cm)**

2 (1). Shell with lateral teeth only on one side of pseudo-cardinal teeth; shell generally large (> 25 mm) and generally oblong (Fig. 3)…..…. …………Freshwater Mussels, **Family Unionidae (p. 10)**

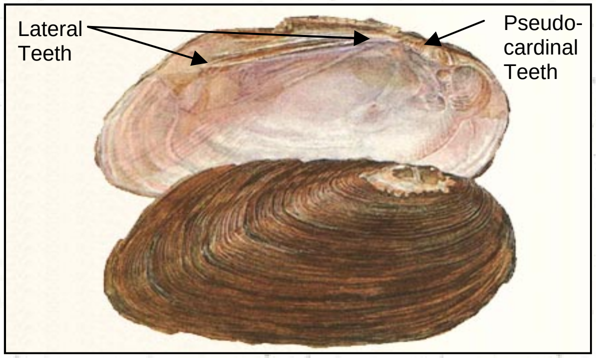


Fig. 3: Example of freshwater mussel showing oblong shape and lateral teeth on one side of pseudo-cardinal teeth.

Freshwater mussels are bivalves with a generally large and oblong shape, with lateral teeth only on one side of pseudo-cardinal teeth. Their shell is usually thick and strong. They are somewhat sensitive to facultative to environmental stress.

2' (1). Shell small (<2.5 cm), resembling a letter D, usually with alternating light and dark bands of color (like zebra stripes); live speciments with byssal threads on bottom of shell (Fig. 4)……………… ……Zebra Mussels , ***Dreissena polymorpha***

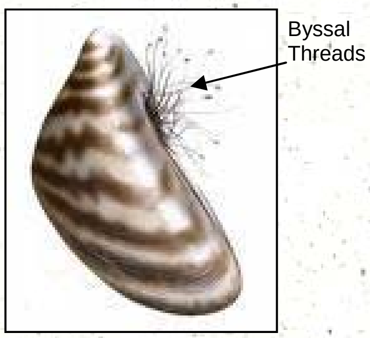


Fig. 4: Example of zebra mussel showing byssal threads, characteristic zebra stripes and D-shape.

Zebra mussels are small bivalves with a characteristic D-shape and zebra striped pattern. Live specimens have byssal threads on the bottom of the shell for attachment. Zebra mussels are exotic and were recently documented in Virginia. They area facultative to environmental stress.

3 (1') . Shell large (25-50 mm) with prominent growth rings; lateral teeth serrated (Fig. 5)..……...Asian Clams, ***Corbicula fluminea***

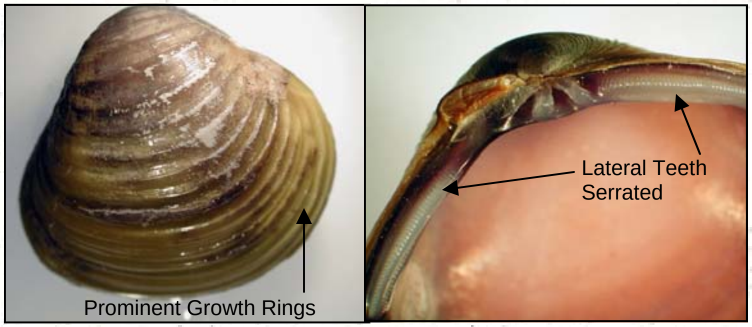


Fig. 5: Example of Asian clam showing prominent growth rings and serrated lateral teeth.

Asian clams are symmetrical-shaped bivalves with prominent growth rings that are conspicuously raised from the shell. Their lateral teeth are serrated. Asian clams are native to southeastern asia and were introduced to the U.S. in the 1930s. They are somewhat sensitive to facultative to environmental stress.

3' (1'). Shell small (<25 mm), thin and fragile, with less prominent growth rings (Fig. 6)……..Fingernail Clams, **Family Pisidiidae, 4**

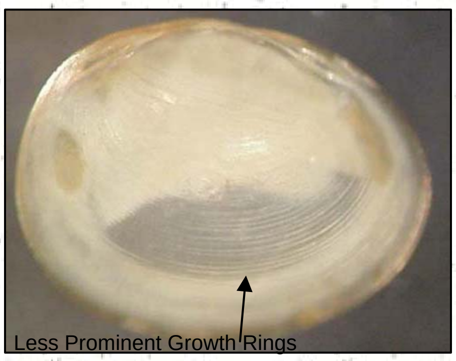
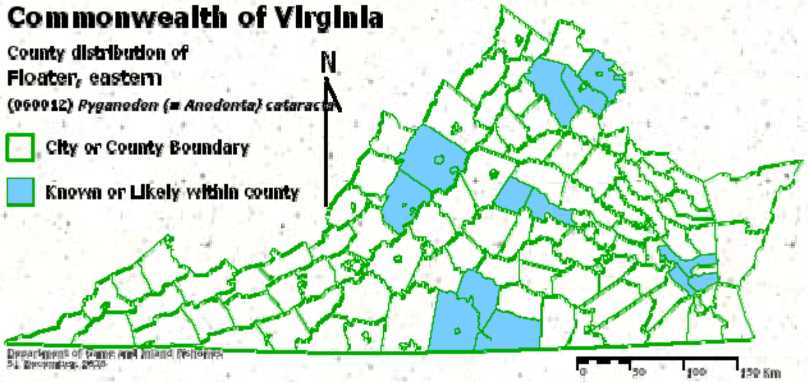


Fig. 6: Example of fingernail clam showing thin and fragile shell and less prominent growth rings.

Fingernail clams are small, more or less symmetrical-shaped bivalves with growth rings that are <u>not</u> conspicuously raised from the shell. Their lateral teeth are <u>not</u> serrated. They are facultative to somewhat tolerant to environmental stress.

Shell shape is ovate, subelliptical and elongate, shells of juveniles not very inflated but much more inflated in adult shells, shells are uniformly thin, often with a low post dorsal wing; shell length 135 mm. The Eastern Floater has no hinge teeth or any indication of swellings in this area. Periostracum is light to dark green, rarely becoming brownish or black, often quite brightly colored, with concentric light and dark bands and with dark green rays most distinct on the disc of the shell, broad green rays on the posterior slope are often well developed, giving the area a much darker color. Nacre is bluish-white.

Habitat includes slow and standing water, including oxbows and sloughs. Substrate includes fine sand, mud, and even silt.
Known host fish include *Ambloplites rupestris, Catostomus commersoni, Cyprinus carpio, Gasterosteus aculeatus, Lepomis gibbosus, Lepomis macrochirus,* and *Perca flavescens.*



PYGANODON CATARACTA
EASTERN FLOATER

- **Thin shelled**
- **Lacks thickening along antero-ventral margin**
- **Relatively long, straight hinge line**
- **Usually medium-large size (< 16 cm)**

4 (3’). Beaks posterior to center of shell, usually obviously so; shell small (<12 mm) (Fig. 6)…………………………………..***Pisidium* sp.**

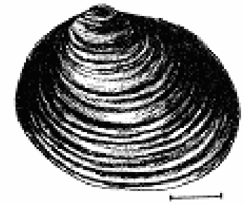


Fig. 6: Example of *Pisidium* showing beak posterior to center of shell.

4’ (3’). Beaks near center or slightly anterior; beaks “capped”; shell often yellowish and translucent (Fig. 7)…………….…***Musculium* sp.**

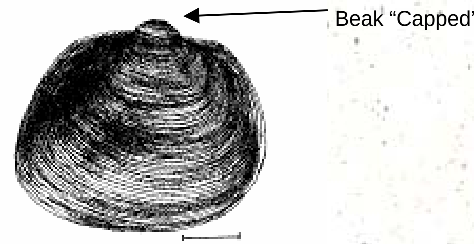


Fig. 7: Example of *Musculium* showing beak “capped” and at center of shell.

4’’ (3’). Beaks near center or slightly anterior; beaks not “capped”; shell usually brown or gray (Fig. 8)…………………..….***Sphaerium* sp.**

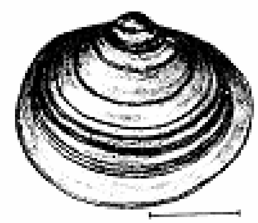


Fig. 8: Example of *Sphaerium* showing beak not “capped” and at center of shell.

FAMILY UNIONIDAE

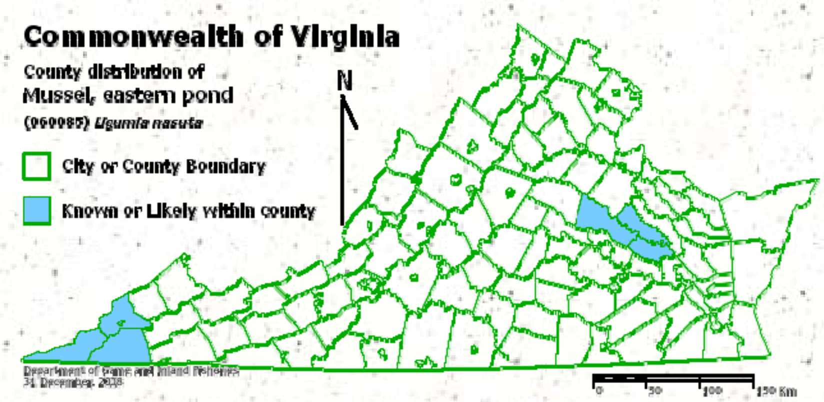
ALASMIDONTA HEDERODON
DWARF WEDGEMUSSEL; FE, SE

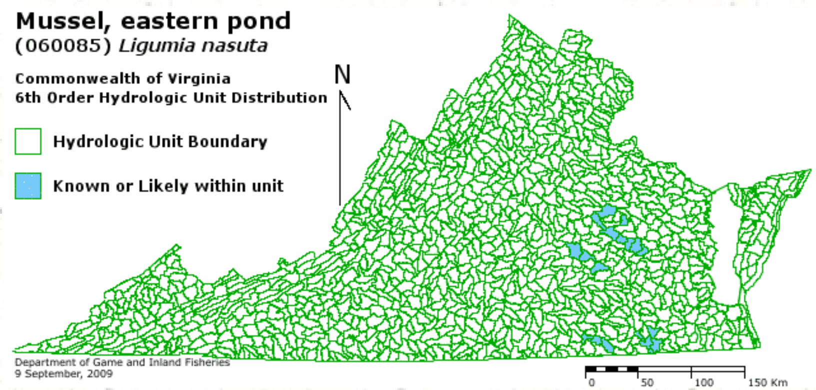
- **Right valve with TWO lateral teeth**
- **Distinctly wedge shaped**
- **Inflated, swollen posterior slope**
- **Small size (< 5 cm)**

Shell shape elongated, subelliptical, thin to subsolid and more or less compressed, shell length 102 mm. Sexual dimorphism in the shells is well marked. The posterior margin of the male shell tapers evenly to a blunt point. The ventral margin of the female shell is expanded in the postbasal region, becoming a broad rounded projection. The posterior ridge is well developed, distinct and angled near the umbo, becoming rounded posteriorly. Periostracum is dark olivegreen to brownish and often with faint dark green, straight and narrow rays present, especially in juvenile specimens. The rays may be completely absent. Nacre is bluish-white, some with salmon in the umbo area, iridescent posteriorly.

Habitat includes quiet standing water of estuaries, lakes and canals, and slow streams. Substrate includes silt and sand (varies).

No host fish is known for this species.



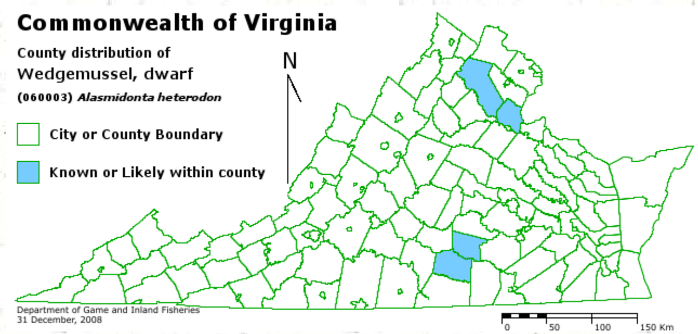


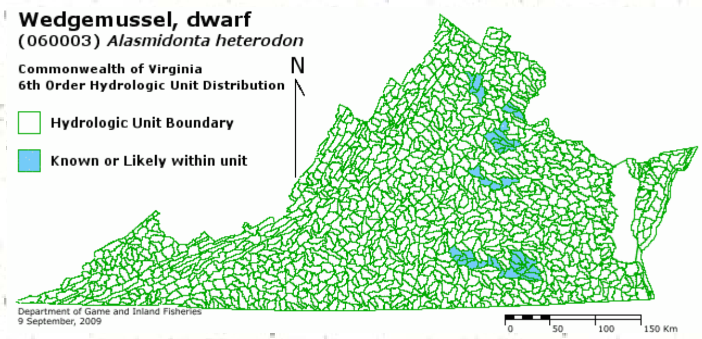
LIGUMIA NASUTA
EASTERN PONDMUSSEL

- **Postero-ventral margin turns abruptly upward**
- **Posterior tip sharp-pointed**
- **Usually medium-large size (< 16 cm)**

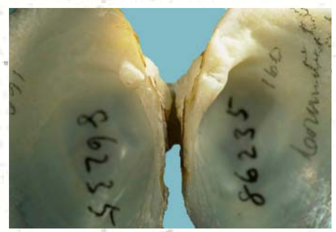
The dwarf wedgemussel is the only Atlantic Coast freshwater mussel in North America that has two lateral teeth on the right vavle, but on ly one one the left. It is small, and rarely exceeds 1.5 inches in length. The shell outline is subrhomboidal or subtrapezoidal, sometimes somewhat elongated. The anterior end is rounded and the posterior end is lengthened and angular.

This mussel reproduces sexually. Eggs are carried in the gills of the female and fertilized as sperm laden water passes through the gills. Glochidia are released in late summer. No fish hosts are known for this species, but it is believed that in some locations the host fish may be anadromous since dams have eliminated some populations of this mussel. The mussels are long term brooders, spawning in late summer, becoming gravid in September, and the glochidia mature in November; Laboratory tests found three host fish that included the tesselated darter (*Etheostoma olmstedi*), Johnnu darter (*E. nigrum*), and mottled sculpin (*Cottus bairdi*) for glochidial development to juvenile stage. The temperature of the water may be a trigger for glochidia release and may coincide with fish entering head waters to spawn. The flow rates may also influence releases, higher flow rates may aid in supporting glochidia in the water column.



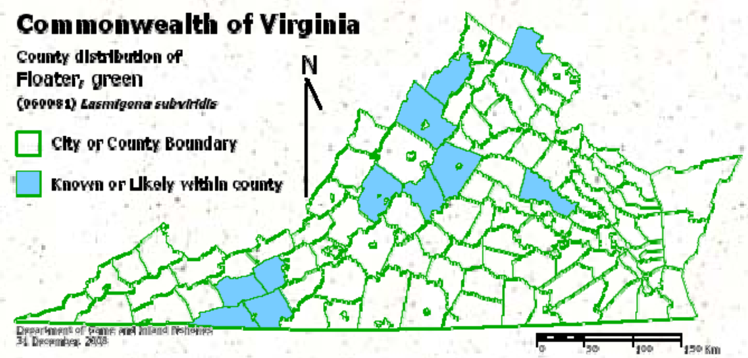


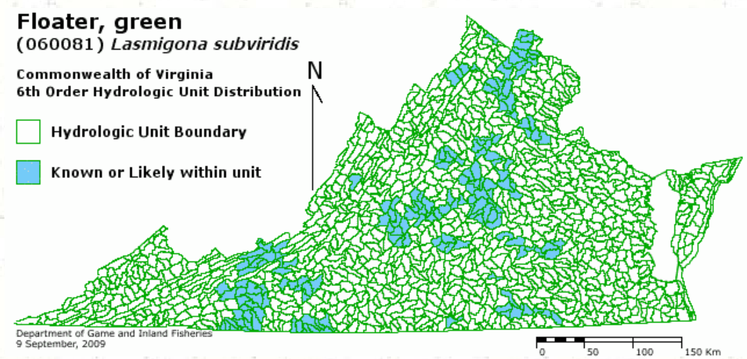
ALASMIDONTA UNDULATA
TRIANGLE FLOATER



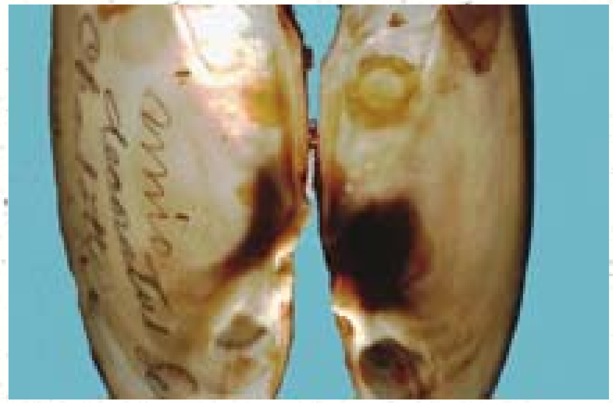
- **No transverse ridges (raised wrinkles) on posterior slope**
- **Pseudocardinal teeth large with rough surfaces**
- **Very inflated, 'squat' appearance, lacks "roman nose"**
- **Small-medium size (< 8 cm)**

The green floater is a small species, usually less than 55 mm in length. It is ovate, trapezoidal or subovate in shape, and unsculptured. The shell is rather fragile and thinner posteriorly. The anterior margin is rounded above and curved below, while the ventral margin is slightly convex or flattened; the posterior margin is sharply rounded or subacute. Beaks are depressed, projecting only a little above the hindge line. The color of the shell is highly variable. The periostracum varies from pale yellow to brownish-green, and is not shiny. Numerous narrow and wide green or blackish rays may be visible on the shell surface. Rays are particularly obvious in juveniles. Annili are marked by concentric grooves that are darkly pigmented in most specimens, and the shell is somewhat compressed with a smooth posterior ridge. Hinge teeth are moderately developed, but very delicate. Pseudocardinal teeth are somewhat elevated; the left valve has two pseudocardinals directed anteriorly, and two long, straight, thin lateral teeth. Lateral teeth are often narrow and shape, but may be incomplete or indistinct. Nacre is white with a bluish iridescent tinge posteriorly, and is thin at the shell margin. The colors and patterns of the perisostracum often show through the nacre. In many specimens, yellow or salmon blotches occur both centrally and near the beak cavity. Habitat includes quiet, meandering parts of hydrologically stable small rivers and smaller streams, most often in slow water or pools and eddies, substrate gravelly or sandy, prefers slower currents. No known hosts; may not require host fish; direct development has been documented.





LASMIGONA SUBVIRIDUS
GREEN FLOATER; ST

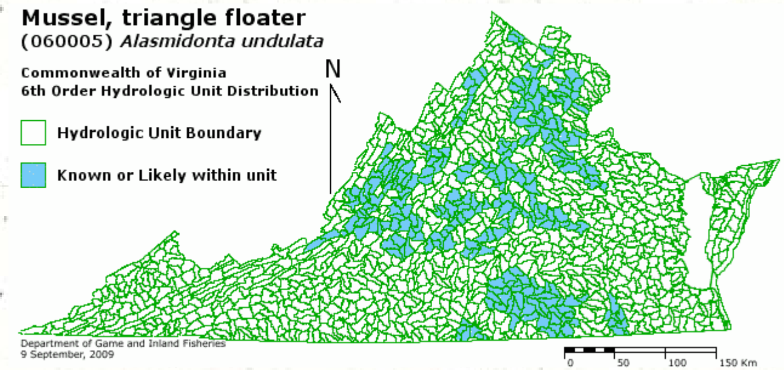


- **Left valve with small interdental tooth, giving appearance of 3 pseudocardinal teeth**
- **Laterally compressed, not inflated**
- **Usually dark green or brown rays present**
- **Small size (< 7 cm)**

The shell shape of the triangle floater is subtriangular to ovate, solid, thicker anteriorly than posteriorly, shell is subinflated to inflated with maximum inflation at the middle of the shell, maximum shell length about 75 mm. Posterior ridge present and usually quite distinct. Posterior slope sometimes marked by oblique ridges or corrugations. Periostracum is smooth and shiny. Periostracum is yellowish, greenish, with broad, green or blackish rays of variable width in juvenile specimens, becoming black with age. Nacre color is typically white anteriorly, but includes salmon, pink or red, becoming iridescent posteriorly.

Habitat includes large creeks and small rivers, sometimes lakes; found in both slow and fast-moving water; substrate may vary from silt/sand in slow-moving water to gravel/sand in fast water.

Known host fish include *Campostoma anomalum*, *Cottus cognatus; Etheostama flobellare*, *Hypentelium nigricans, Lepomis gibbosus Luxilus cornutus, Micropterus salmoides, Notropis rubellus, Rhinichthys atratulus, Rhinichthys cataractae, and Semotilus corporalis*



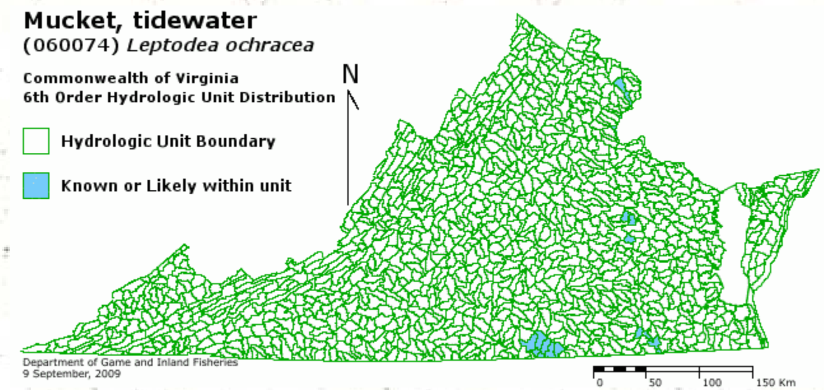
ALASMIDONTA VARICOSA
BROOK FLOATER; SE

- **Transverse ridges (raised wrinkles) on posterior slope**
- **Pseudocardinal teeth reduced and elongate with smooth surfaces**
- **Moderately inflated, distinctive posterior ridge (“roman nose”)**
- **Small-medium size (< 8 cm)**

Shells of the Tidewater Mucket are usually relatively small, at times nearly 100 mm in length, elliptical to ovate in outline with a thin to subsolid, strong, subinflated shell. Posterior ridge is well developed ending in a blunt point about half way up from the base on the posterior margin. The periostracum is slightly shiny to mat. The interdentum is virtually nonexistent in this species. Periostracum is dull, not a bright yellow but grayish, greenish, or brownish olive and the rays have a different character. The rays become obscure on the posterior slope. Nacre is white to reddish pink.

Habitat includes freshwater tidal rivers, standing coastal ponds including oxbows and sloughs, quiet tidal water. Substrate includes silt and mud

Known host fish include *Morone americana*.



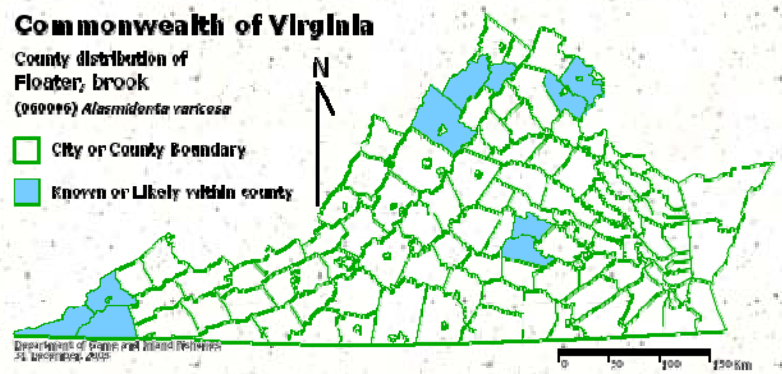
LEPTODEA OCHRACEA
TIDEWATER MUCKET

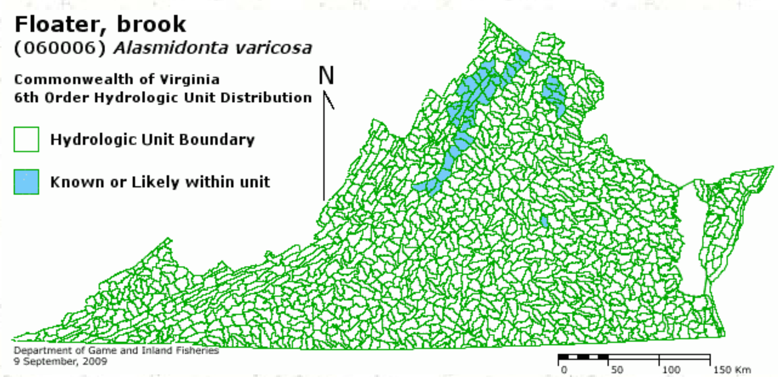
- **Periostracum dull yellow, sometimes with fine rays over part or most of shell**
- **Nacre usually pinkish to salmon-colored**
- **Ventral margin rounded**
- **Moderately thin-shelled**
- **Inflated appearance**
- **Hinge teeth thin and delicate**
- **Pseudocardinal teeth located well anterior of beak**
- **Usually medium-large size (< 16 cm)**

Shell shape of the brook floater is oblong, long rhomboid, thin-shelled, slightly inflated with the maximum inflation at the posterior ridge, maximum length is about 70 mm. Posterior ridge is broad, rounded, and inflated. Periostracum is yellowish but more often greenish and partly or completely covered with dark greenish rays in juveniles, becoming brownish with rays partially obscured to almost black in adult specimens.

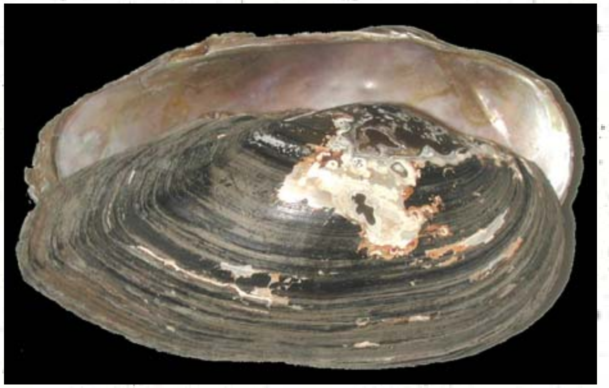
Habitat includes creeks and small rivers, typically in fast water on a substrate of stable gravel or sandy shoals.

Known host fish include *Cottus cognatus, Lepomis gibbosus, Notemigonus crysoleucas, Noturus insignis, Perca flavescens, Rhinichthys atratulus,* and *Rhinichthys cataractae*





ANODONTA IMPLICATA
ALEWIFE FLOATER

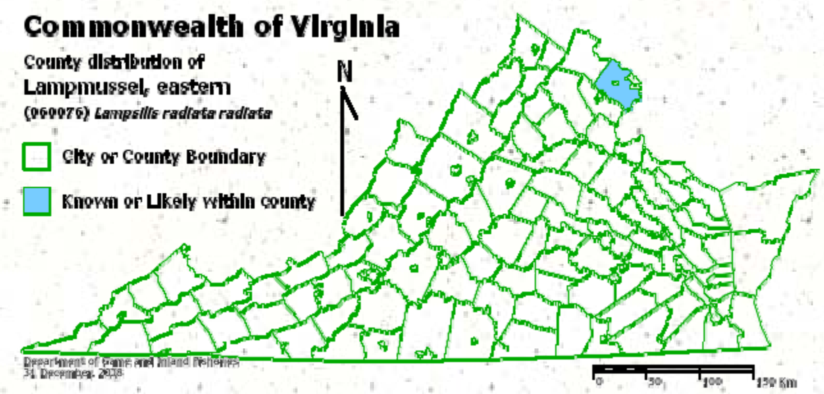


- **Thick shelled**
- **Distinct thickening along antero-ventral margin**
- **Relatively long, straight hinge line**
- **Usually medium-large size (< 16 cm)**

Shell shape of eastern lampmussel is subelliptical to subovate in outline, shell valves are thick and solid, shell valves vary from hardly inflated to quite inflated, shell length is often greater than 120 mm. Interdentum is lacking. Periostracum is yellowish or brownish green with dark
green or black rays over the entire surface, rays are not well defined. Nacre color is white, may be tinged with pink or salmon or may be completely pink or salmon.

Habitat includes most creeks, rivers and lakes; found in all types of flows and a wide variety of substrates but favors coarse sand and gravel.

Know fish hosts include *Ambloplites rupestris, Lepomis gibbosus, Lepomis cyanellus, Lepomis megalotis*, *Micropterus dolomica* , *Micropterus salmoides*, *Morone Americana, Natropis ludibundus* , *Perca flavescens, Pimephales notatus,* and *Poxomis nigromaculatus.*



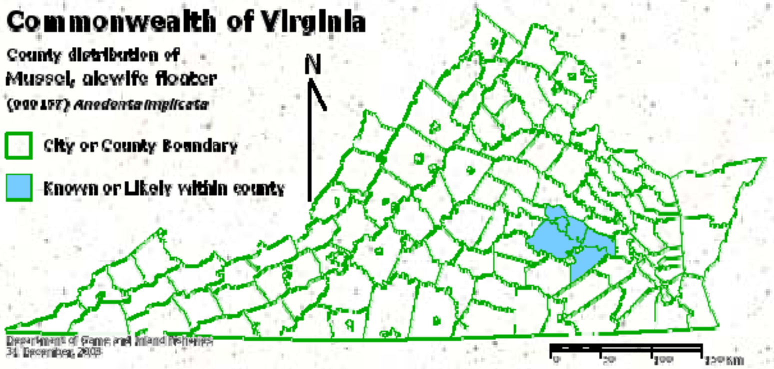
LAMPSILIS RADIATA
EASTERN LAMPMUSSEL; SS

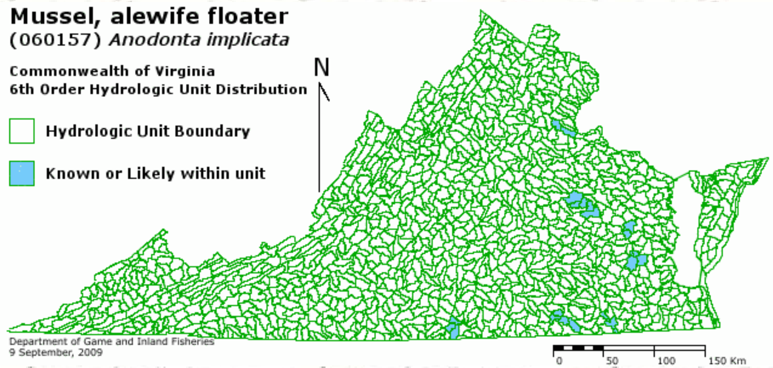
- **Periostracum usually yellow to yellowish green, with green rays over most of shell**
- **Laterally compressed**
- **Palmate shaped, distinctly wider posterior to umbo**
- **Hinge ligament prominent posterior to umbo**
- **Relatively heavy-shelled**
- **Usually medium-large size (< 16 cm)**

Shell shape of the alewife floater is elliptical, oblong to ovate in outline, approaching subcylindrical in cross-section, shell thickness rather solid, with a pronounced thickening of the anterior ventral margin from about the middle of the shell anterior, inflated, shell length reaching about 142 mm. This is a typical Anodonta completely lacking any indication of pseudocardinal or lateral teeth.

Habitat includes slow, sometimes fast running water, and also quiet standing water. Substrate includes cobble.

Known host fish include *Alosa pseudoharengus, Catostomus commersoni, Gasterosteus aculeatus*, *Lepomis gibbous*, and *Morone Americana*.





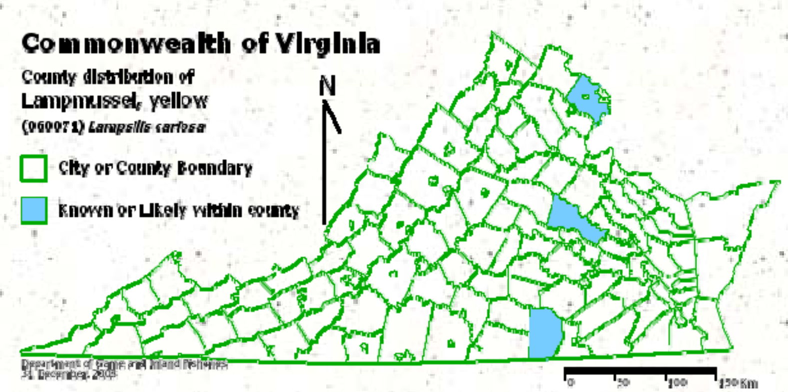
ELLIPTIO COMPLANATA
EASTERN ELLIPTIO

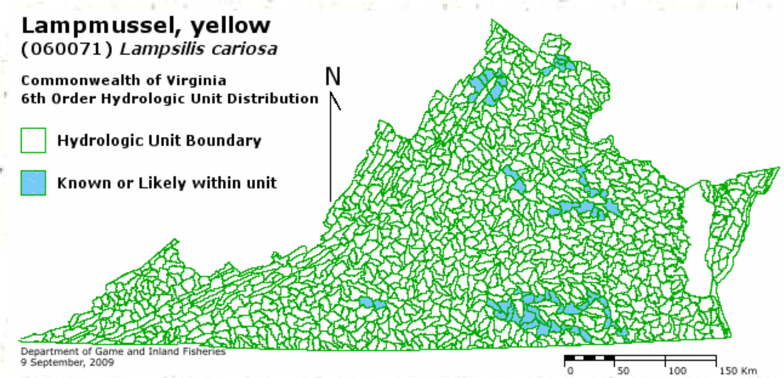
- **Not elongate, height/length ratio > 0.5**
- **Typical shell shape is quadrate or rectangular**
- **With or without rays**
- **Umbos not prominent, barely above hinge line**
- **Usually not inflated or with swollen posterior slope**
- **Relatively heavy-shelled**
- **Nacre distinctly purple in fresh dead specimens, variable otherwise**
- **Usually medium-large size (< 16 cm)**
- **Highly variable – when in doubt, call it *E. complanata* ???**

Shell shape is obovate, shell thickness begins as thin in juveniles becoming thicker with age, moderately inflated, shell length 120 mm. Periostracum is waxy and shiny. Interdentum is narrow but obvious compared with Leptodea ochracea. Periostracum is waxy yellow, often with a trace of green in it, rays are either absent or restricted to the posterior slope or slightly in front of it. The nacre is bluish-white, often tinged with cream or salmon.

Habitat includes small to large rivers with moderate to fast flow, especially in riffles. Preferred substrate includes sand and gravel, or shifting sands downstream from large boulders. Species of *Lampsilis* favor rivers, but may be found as well in streams and lakes where they tolerate a wide range of conditions.

Known fish hosts include *Morone americana* and *Perca flavescens.*





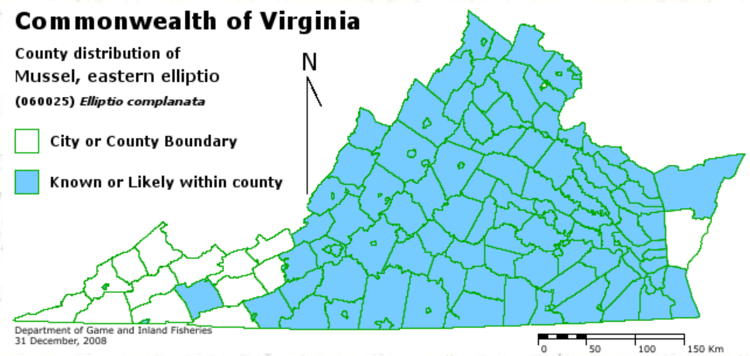
LAMPSILIS CARIOSA
YELLOW LAMPMUSSEL; SS

- **Green rays, if present, thin and mostly confined to posterior half of shell**
- **Pseudocardinal teeth on left valve with striations and perpendicular to hinge line**

Shell shape of the eastern elliptio is trapezoidal to rhomboid or subelliptical, compressed to inflated, shell thickness varies from thin to solid, length 120 mm. The posterior slope is flat. Periostracum is yellowish to brown and blackish. Young specimens have indistinct greenish rays present. The rays generally disappear in older shells. Nacre varies from white, pink, salmon, to various shades of purple.

The eastern elliptio is found in virtually any large pond, lake, stream, or river, where it is nearly always the most abundant mussel species. It can be found in all types of substrates.

Known host fish include *Perca flavescens*, which is the only verified host. Other suspected hosts include *Fundulus diaphanous, Lepomis cyanellus, Lepomis humilo*, *Micropterus salmoides,* and *Pomoxis annularis.*



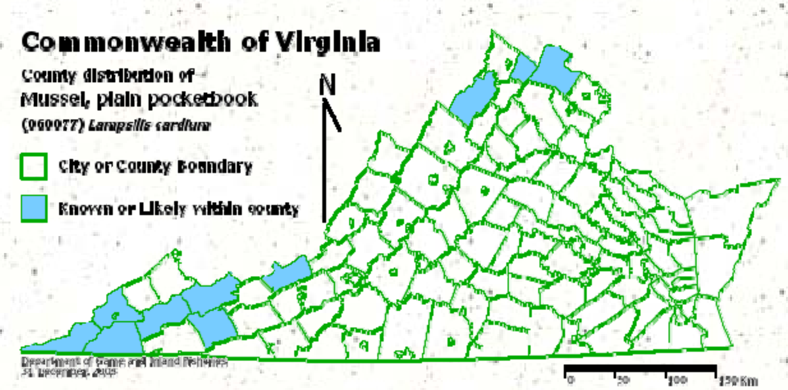
ELLIPTIO ANGUSTATA
CAROLINA LANCE

- **Postero-ventral margin does NOT turn abruptly upward**
- **Posterior tip bluntly pointed**
- **Periostracum usually not yellow or waxy**
- **Usually medium-large size (< 14 cm)**
- **Difficult to distinguish from *E. producta* and *E. fisheriana***

Shell of plain pocketbook large, round or somewhat quadrate, thin to moderately thick (particularly in older individuals), and inflated. Anterior end rounded, posterior end bluntly pointed (males) to truncated (females). Dorsal and ventral margins straight to curved. Umbos turned forward and elevated above the hinge line. Beak sculpture of four or five elevated ridges. Periostracum smooth, yellow or yellowish green, usually with numerous dark green rays of various widths. Length to 7 inches (17.8 cm). Pseudocardinal teeth relatively large, elevated, and roughened in young individuals, smoother in old specimens; two in the left valve, one in the right. Lateral teeth straight to curved, moderate in length, and striated. Beak cavity deep. Nacre white or bluish white, occasionally pink or salmon, iridescent posteriorly.

Habitat includes small creeks to large rivers in mud, sand, or gravel.

Note that this species is native to the Mississippi River drainage and was recently introduced to the Chesapeake Bay. It is known to hybridize with the yellow lampmussel (*Lampsilis cariosa*) and can be difficult to distinguish.

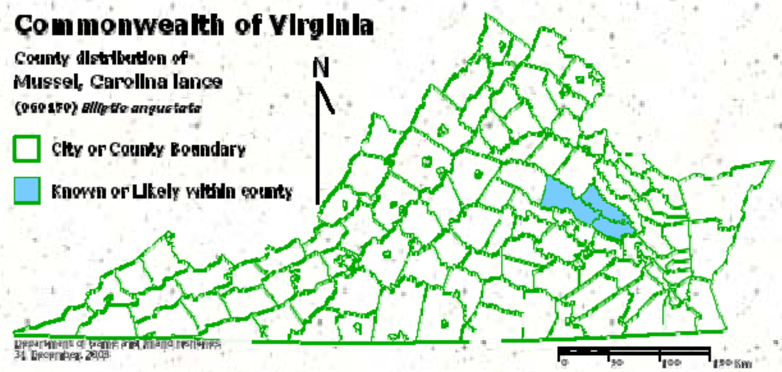


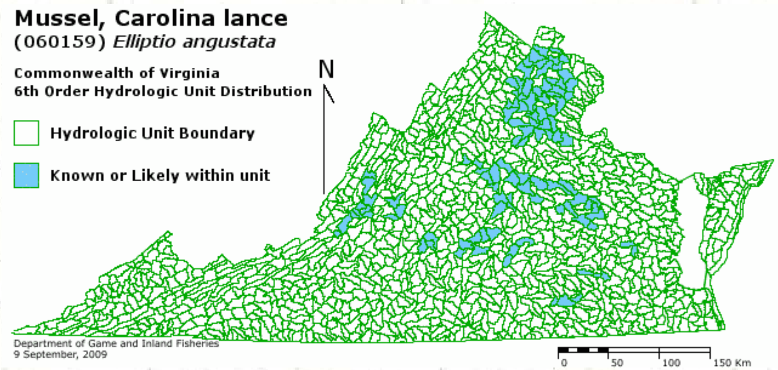
LAMPSILIS CARDIUM
PLAIN POCKETBOOK

- Green rays usually present, thick and not
- confined to posterior half of shell
- Pseudocardinal teeth on left valve without striations and parallel to hinge line

Shell of Carolina lance is elongate, elliptical to subrhomboid and slightly compressed and rather thin, shell length to 140 mm. Posterior ridge is well developed, often double ending slightly below the middle of the posterior end of the shell. Periostracum is olive becoming nearly black in older specimens. Nacre is a shade of purple.

The Carolina lance seems to prefer sand and sandy gravel substrates and is often found at the edge of aquatic vegetation.



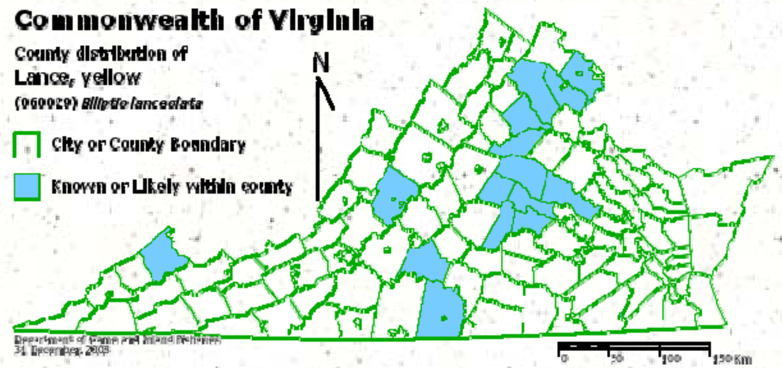


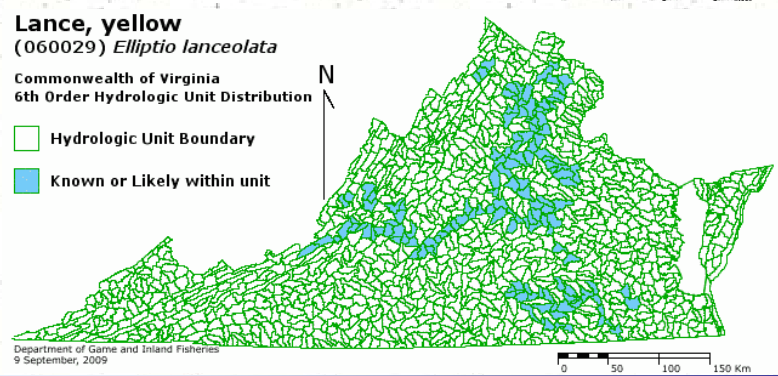
ELLIPTIO FISHERIANA
NORTHERN LANCE

- Postero-ventral margin does NOT turn abruptly upward
- Posterior tip bluntly pointed
- Periostracum usually not yellow or waxy
- Usually medium-large size (< 16 cm)
- Difficult to distinguish from *E. angustata* and *E. producta*

This elongate freshwater mussel grows to approximately 86 mm long. Shells are over twice as long as tall. The periostracum is usually a waxy, bright yellow over the entire surface in younger individuals. Older individuals may have a brown discoloration on the posterior end of the shell. The nacre may range form salmon to white to an iridescent blue. The posterior ridge is distinctly rounded and curves dorsally toward the posterior end. Rays are usually never present. Brownish growth rests are clearly evident on the periostracum. The pallial line and adductor muscle scars are distinct. The posterior adductor muscle scars are less impressed than the anterior adductor muscle scars. The lateral teeth are long - two on the left valve and one on the right valve. Two pseudocardinal teeth are on each valve. On the left valve, one is before the other with the posterior tooth tending to be vestigial. On the right valve, the two pseudocardinal teeth are parallel with the more anterior one rather vestigial.

This species prefers clean, coarse to medium sized sands as substrate. On occasion, specimens are also found in gravel substrates. This species is found in the main channels of drainages down to streams as small as a meter across.

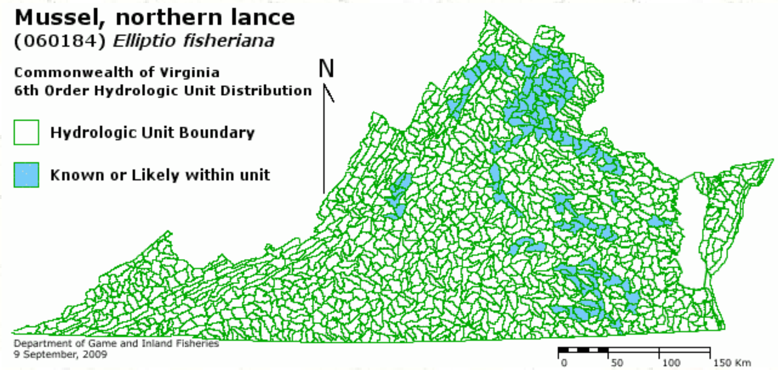




ELLIPTIO LANCEOLATA
YELLOW LANCE; FS, SS

- **Postero-ventral margin does NOT turn abruptly upward**
- **Posterior tip bluntly pointed**
- **Periostracum usually waxy yellow**
- **Usually small-medium size (< 8 cm)**

The northern lance is similar in appearance to both the Carolina lance (*E. angustata*) and the Atlantic spike (*E. producta*). Data in Maryland indicates that the Northern lance is found east of the Chesapeake Bay, whereas the Atlantic spike is found west of the Chesapeake Bay. However, this does not seem to be the case in Virginia.

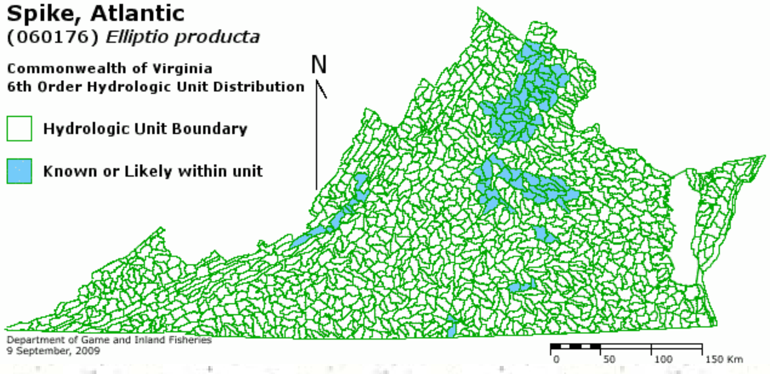


ELLIPTIO PRODUCTA
ATLANTIC SPIKE

- **Postero-ventral margin does NOT turn abruptly upward**
- **Posterior tip bluntly pointed**
- **Periostracum usually not yellow or waxy**
- **Usually medium-large size (< 16 cm)**
- **Difficult to distinguish from *E. angustata* and *E. fisheriana***

Shell of Atlantic spike elongate, somewhat compressed, solid, with a maximum length of nearly 140 mm. Anterior margin is rounded, posterior margin roundly pointed with the most posterior point slightly above the midline of the shell. Periostracum has fine uneven incremental growth lines, slightly shiny, dark reddish-brown or greenish-brown without rays. Nacre is a shade of purple.

The atlantic spike is similar in appearance to both the Carolina lance (*E. angustata*) and the Northern lance (*E. fisheriana*). Data in Maryland indicates that the Northern lance is found east of the Chesapeake Bay, whereas the Atlantic spike is found west of the Chesapeake Bay. However, this does not seem to be the case in Virginia.



APPENDIX H:

DEFINITIONS OF METRICS AND INDICES FOR USE IN WSSI BIOLOGICAL STREAM ASSESSMENTS

Appendix H. Definitions of Metrics and Indices for use in WSSI Biological Stream Assessments.

METRICS

EPT Taxa Richness. EPT Taxa Richness represents the number of taxa from the aquatic insect orders Ephemeroptera, Plecoptera, and Trichoptera. EPT taxa are generally very sensitive to pollution. Total EPT Taxa Richness is expected to be relatively high in undisturbed streams, and it is expected to decrease in response to environmental disturbance.

Percent Chironomidae. The Percent Chironomidae represents the ratio of members of the aquatic insect family Chironomidae (non-biting midges) to the total number of individuals in a sample. Because chironomids are generally tolerant to pollution, Percent Chironomidae is expected to increase in response to environmental disturbance.

Percent Clingers. The Percent Clingers represents the percentage of taxa adapted primarily for inhabiting flowing water, as in riffles. Designated clinger taxa were obtained from the DNR MBSS master list with designated tolerance values, functional feeding groups, and habitats. Percent Clingers is expected to decrease in response to environmental disturbance.

Percent Ephemeroptera. The Percent Ephemeroptera represents the ratio of members of the aquatic insect order Ephemeroptera (mayflies) to the total number of individuals in a sample. Mayflies are generally very sensitive to pollution, thus Percent Ephemeroptera is expected to decrease in response to environmental disturbance.

Percent Plecoptera + Trichoptera (Excluding Hydropsychidae). The Percent Plecoptera + Trichoptera (Excluding Hydropsychidae) represents the ratio of members of the aquatic insect orders Plecoptera (stoneflies) and Trichoptera (caddisflies) (excluding the those in the pollution tolerant family Hydropsychidae) to the total number of individuals in a sample. Percent Plecoptera + Trichoptera (Excluding Hydropsychidae) is expected to decrease in response to environmental disturbance.

Percent Scrapers. The Percent Scrapers represents the ratio of taxa adapted primarily for scraping food from a substrate to the total number of individuals in a sample. Percent Scrapers is expected to increase in response to environmental disturbance.

Percent Top Two Dominant. The Percent Top Two Dominant is the ratio of the top two most abundant taxa in a sample to the total number of individuals in a sample. Percent Scrapers is expected to increase in response to environmental disturbance.

Total Taxa Richness. Total Taxa Richness represents the total number of taxa in a sample. Total Taxa Richness is expected to be relatively high in undisturbed streams and is expected to decrease in response to environmental disturbance.

INDICES

Hilsenhoff Biotic Index. The Hilsenhoff Biotic Index is the abundance-weighted average tolerance of assemblage of organisms (Family taxonomic level).

Stream Condition Index. The Stream Condition Index takes the weighted average of Percent Ephemeroptera, Percent Plecoptera + Trichoptera (Excluding Hydropsychidae), Percent Scrapers, Percent Chironomidae, Total Taxa, EPT Taxa, and Percent Top Two Dominant. The weighting is as follows:

Total Taxa: Score = 100 x (X/22), where X = Metric Value
EPT Taxa: Score = 100 x (X/11), where X = Metric Value
% Ephemeroptera: Score = 100 x (X/61.3), where X = Metric Value
% Plecoptera + Trichoptera less Hydropsychidae: Score = 100 x (X/35.6), where X = Metric Value
% Scrapers: Score = 100 x (X/51.6), where X = Metric Value
% Chironomidae: Score = 100 x [(100-X) (100-0)], where X = Metric Value
% Top 2 Dominant: Score = 100 x [(100-X) (100-30.8)], where X = Metric Value
Hilsenhoff Biotic Index: Score = 100 x [(100-X) (100-3.2)], where X = Metric Value

The scoring thresholds are as follows:

NUMERICAL SCORE	NARRATIVE SCORE
<42	Severe Stress
43-59	Stress
60-72	Good
>73	Excellent

Coastal Plain Macroinvertebrate Index
The CPMI is calculated by adding the weighted scores of Total Taxa, EPT Taxa, % Ephemeroptera, % Clingers, and HBI. The weighting and scoring thresholds are as follows:

Metric Scoring Criteria				
Metric	**6**	**4**	**2**	**0**
1. Total Taxa	>17	12-17	6-11	<6
2. EPT Taxa	>6	5-6	3-4	<3
3. % Ephemeroptera	>24%	16-24%	8-15%	<8%
4. HBI	<5.7	5.7-6.4	6.5-7.2	>7.2
5. % Clingers	>26%	18-26%	9-17%	<9%

NUMERICAL SCORE	NARRATIVE SCORE
24-30	Severe Stress
16-22	Stress
6-14	Good
0-4	Excellent

Exhibit 2

Certificates of Training and Certifications of Various WSSI Staff

TAXONOMIC CERTIFICATION

This certificate is awarded to

ALLY ST. ONGE

In recognition of Image Identification to
Family Level
All Phyla

NORTH AMERICAN BENTHOLOGICAL SOCIETY

Dr. Murray Colbo

Date Sept., 2009

Wetland
Studies and Solutions, Inc.®

This certificate is awarded to

Ally St. Onge

for completion of the Introduction to the Taxonomy of

Ephemeroptera, Plecoptera, and Trichoptera

workshop held from June 15th - 17th 2010.

Wetland Studies and Solutions, Inc.

6-17-10

Sean D. Sipple, CE, CT, PWS, PWD — *Date*

6-17-10

Mark Headly, PWS, PWD, LEED® AP — *Date*

Virginia Association of Wetland Professionals

Presents this certificate for successful attendance at the

VAWP 2011 Benthic Macro-Invertebrate Workshop

Training was provided on the identification and use of benthic macro-invertebrates in the assessment of stream condition and health

to

Alison St. Onge

on this 13th day of May, Two Thousand and Eleven

Tara Fisher

Program Chair, Virginia Association of Wetland Professionals

Wildland Hydrology, Inc.

Research and Educational Center for River Studies

Awards this Training Certificate to:

Alison Robinson

Applied Fluvial Geomorphology

April 8-12, 2013

NCTC - Shepherdstown, WV

David L. Rosgen, P.H., Ph.D.

Taxonomic Certification

This certificate is awarded to

Candice Kerling

BENJAMIN ROSNER

In recognition of Image Identification to

Family Level

All Phyla

NORTH AMERICAN BENTHOLOGICAL SOCIETY

NORTH AMERICAN BENTHOLOGICAL SOCIETY FOUNDED 195

Dr. Murray Colbo

Date April, 2009

ECOLOGICAL SOCIETY OF AMERICA

esa

The Ecological Society of America

Founded 1915

The Ecological Society of America,
upon recommendation of the
Board of Professional Certification, hereby certifies that

Benjamin N. Rosner

meets the requirements as a certified

Ecologist

and is governed by the Society's Code of Ethics.*

Certified by the Ecological Society of America from
June 1, 2009 through June 30, 2014

President, Ecological Society of America

Chair, Board of Professional Certification

Wetland
Studies and Solutions, Inc.®

This certificate is awarded to

Benjamin Rosner

for completion of the Introduction to the Taxonomy of

Ephemeroptera, Plecoptera, and Trichoptera

workshop held from June 15th - 17th 2010.

Wetland Studies and Solutions, Inc.

Sean D. Sipple, CE, CT, PWS, PWD	6-17-10 *Date*
Mark Headly, PWS, PWD, LEED® AP	6-17-10 *Date*

Certificate of Completion

THIS ACKNOWLEDGES THAT

Ben Rosner

HAS SUCCESSFULLY COMPLETED THE
IDENTIFICATION AND TAXONOMY OF MUSSELS
ON APRIL 5, 2013 AT THE ASSOCIATION OF MID-ATLANTIC AQUATIC BIOLOGIST (AMAAB) WORKSHOP AT CACAPON STATE PARK, WEST VIRGINIA

ARTHUR E. BOGAN, PH.D. FLS
, RESEARCH CURATOR OF AQUATIC INVERTEBRATES NORTH CAROLINA STATE MUSEUM OF NATURAL SCIENCES RALEIGH , NORTH CAROLINA

RICK SPEAR, AQUATIC BIOLOGIST SUPERVISOR
PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION, SOUTHWEST REGIONAL OFFICE PITTSBURGH, PENNSYLVANIA

WILDLAND HYDROLOGY, INC.

Research and Educational Center for River Studies

Awards this Training Certificate to

Ben Rosner

For completion of

Applied Fluvial Geomorphology

July 19, 2004 through July 23, 2004

Lubrecht Forest, Montana

Dave Rosgen

Dr. David L. Rosgen

WILDLAND HYDROLOGY, INC.

Research and Educational Center for River Studies

Awards this Training Certificate to

Ben Rosner

For completion of

River Morphology and Applications

February 20th – 24th, 2006

Gainesville, Virginia

David L. Rosgen, Ph.D

TAXONOMIC CERTIFICATION

This certificate is awarded to

Candice Kerling

JENNIFER FEESE

In recognition of Image Identification to

Family Level

All Phyla

NORTH AMERICAN BENTHOLOGICAL SOCIETY

Dr. Murray Colbo

Date June, 2009

U.S. FISH & WILDLIFE SERVICE

DEPARTMENT OF THE INTERIOR

U.S. Fish & Wildlife Service

National Conservation Training Center

This is to certify that

JENNIFER FEESE

has successfully completed

Biological Monitoring of Stream Restoration

July 7-11, 2008 * Shepherdstown, WV

Gary Schetrompf/Course Leader
Branch of Conservation Science and Policy Training

Christopher M. Horsch, Chief
Branch of Conservation Science and Policy Training

ATKINS

Certificate of Attendance

JENNIFER FEESE

Wetland Studies and Solutions

Surface Water ID and Training Course (SWITC)

May 11, 2012

Raleigh, NC

Credit Hours: 30.00 PDH

Curriculum provided by NC Division of Water Quality

John D rney, Facilitator

CEO/President Atkins North America

Atkins University

WILDLAND HYDROLOGY, INC.

Research and Educational Center for River Studies

Awards this Training Certificate to

Jennifer Feese

For completion of

Applied Fluvial Geomorphology

October 24th – 28th, 2005

Fayetteville, AR

David L. Rosgen, Ph.D

WILDLAND HYDROLOGY, INC.

Research and Educational Center for River Studies

Awards this Training Certificate to

Jennifer Feese

For completion of

River Morphology and Applications

February 20th – 24th, 2006

Gainesville, Virginia

David L. Rosgen, Ph.D

TAXONOMIC CERTIFICATION

This certificate is awarded to

Candice Kerling

JENNIFER VANHOUTEN

In recognition of Image Identification to

Family Level

All Phyla

NORTH AMERICAN BENTHOLOGICAL SOCIETY

Dr. Murray Colbo

Date April, 2009

ECOLOGICAL SOCIETY OF AMERICA

esa

The Ecological Society of America

Founded 1915

The Ecological Society of America,
upon recommendation of the
Board of Professional Certification, hereby certifies that

Jennifer W. Van Houten

meets the requirements as a certified

Ecologist

and is governed by the Society's Code of Ethics.

Certified by the Ecological Society of America from
June 1, 2009 through June 30, 2014

President, Ecological Society of America

David D. Breshears
Chair, Board of Professional Certification

Wetland

Studies and Solutions, Inc.®

This certificate is awarded to

Jennifer Van Houten

for completion of the Introduction to the Taxonomy of

Ephemeroptera, Plecoptera, and Trichoptera

workshop held from June 15th - 17th 2010.

Wetland Studies and Solutions, Inc.

6-17-10

Sean D. Sipple, CE, CT, PWS, PWD — *Date*

6-17-10

Mark Headly, PWS, PWD, LEED® AP — *Date*

WILDLAND HYDROLOGY, INC.

Research and Educational Center for River Studies

Awards this Training Certificate to

Jennifer Van Houten

For completion of

River Morphology and Applications

February 20th – 24th, 2006

Gainesville, Virginia

David L. Rosgen, Ph.D

TAXONOMIC CERTIFICATION

This certificate is awarded to

Candice Kerling

BETH CLEMENTS

In recognition of Image Identification to
Family Level
All Phyla

NORTH AMERICAN BENTHOLOGICAL SOCIETY

Dr. Murray Colbo

Date May, 2009

Wetland

Studies and Solutions, Inc.®

This certificate is awarded to

Beth Clements

for completion of the Introduction to the Taxonomy of

Ephemeroptera, Plecoptera, and Trichoptera

workshop held from June 15th - 17th 2010.

Wetland Studies and Solutions, Inc.

	6-17-10
Sean D. Sipple, CE, CT, PWS, PWD	*Date*
	6-17-10
Mark Headly, PWS, PWD, LEED® AP	*Date*

ATKINS

Certificate of Attendance

BETH CLEMENTS

Wetland Studies and Solutions

Surface Water ID and Training Course (SWITC)

May 11, 2012

Raleigh, NC

Credit Hours: 30.00 PDH

Curriculum provided by NC Division of Water Quality

John Dorney, Facilitator

CEO/President Atkins North America

Atkins University

WILDLAND HYDROLOGY, INC.

Research and Educational Center for River Studies

Awards this Training Certificate to

Beth Clements

For completion of

River Morphology and Applications

November 10th – 14th, 2008

Fayetteville, AR

David L. Rosgen, Ph.D.

Exhibit 3

Specifications and Instructions for Using and Calibrating the YSI 556 Multi-Probe System (MPS)

SPECIFICATIONS AND INSTRUCTIONS FOR USING AND CALIBRATING THE YSI 556 PRO PLUS MULTI PROBE SYSTEM (MPS)

1. NOTES

a. Read over and file MSDS for each calibration product, for some products may be hazardous to your health. Please follow precautions and disposal instructions.
b. When assembling unit, refer to Users Manual for instructions.
c. When unit is not in use for up to one month, store electrodes in calibration/transport sleeve with sponge (supplied) soaked in deionized water to provide a 100% saturated air environment.
d. When unit is not in use for ≥ one month, remove the dissolved oxygen membrane cap, thoroughly rinse the sensor, dry, and use a clean, dry new membrane cap to screw over the sensor to keep it dry and to protect the anode and cathode. Additionally, store pH electrode in the small pH 7 solution bottle to provide a saturated air environment (provided by YSI on delivery, with solution already in it). Then, store all electrodes dry in calibration cup or Probe Sensor Guard (See manual for more specific instructions).
e. Replace electrolyte solution in membrane cap every 2-8 weeks when being used daily.
f. When taking water quality readings in the field, always use probe sensor guard to protect electrodes.
g. Conductivity Calibrator solution should be stored between 0 and 30 degrees C. Discard unused solution one month after opening.
h. There are no specifications for pH storage temperature. Therefore, it can be stored at room temperature. Read label for expiration.

2. PRODUCT CALIBRATION

a. *Dissolved oxygen*

- The YSI offers 3 methods that can be used to calibrate DO; first using air calibration in % saturation; second calibrates in mg/L to a solution with a known DO concentration (either of these methods will automatically calibrate the other); third is a zero calibration (in which you have to perform either the % or mg/L calibration following).
- The following is the % saturation calibration (easiest).
  - *i.* Moisten the sponge in the cal/transport sleeve and loosely screw onto probes to provide contact with atmosphere. **Make sure the DO and temperature sensors are NOT immersed in the water.**

1. Press on/off button
2. Use “Cal” hot key then highlight DO, then press Enter
4. Highlight DO%, then press Enter
5. Verify barometric pressure. Once DO and temperature are stable, highlight Accept Calibration and press Enter. The screen will indicate that the calibration was accepted.

b. *Conductivity*

1. Select “Cal” hot key on keypad
2. Using the arrows, highlight “Conductivity”, and press enter
3. Pick from the options for calibrating Specific Conductance, Conductivity, or Salinity (calibrating one will automatically calibrate the others). Additionally, you will have to choose the units you want conductivity displayed in.
4. Fill cal/transport cup completely with conductivity solution and gently place probes in and tighten to ensure there are no bubbles in solution.
7. Allow approximately 1 minute for temperature to stabilize
8. Highlight the Calibration Value and enter the known conductivity of the solution into the YSI.
9. When the readings stabilize, highlight Accept Calibration and press Enter. The screen will indicate that the calibration was accepted. Press Enter again
10. Press escape to return to the calibrate menu
11. Clean the calibration cup and electrodes with water and dry completely

c. *pH*

1. Select “Cal” hot key on keypad
2. Using the arrows, highlight “pH”, then press Enter. The pH calibration allows up to a 6 point calibration.
3. Place enough of the buffer solution in the cal/transport cup to cover the pH probes and insert probes into cal/transport cup.
4. Once reading is stable, highlight Accept Calibration and press Enter
5. Screen will read Ready for Second Point and the process will repeat.
6. **Press “Cal” to complete calibration** after reaching desired number of buffer calibrations or press Esc to cancel the calibration.

3. FIELD SETUP AND USE

Remove the unit from storage and replace the cal/transport cup with the guard cup.

1. Turn on. The instrument will be in Run mode when powered on.

2. Connect the two ends of the data cable to the probe and instrument.

3. To take readings, insert the probe into the stream, perpendicular to the flow, until all the sensors are covered. Keeping the probes submerged; agitate the probe gently until the readings stabilize. This releases any air bubbles and provides movement if measuring DO.

4. Use the Habitat Assessment Form to record the stabilized values of the water chemistry readings (the YSI allows for recording of values singly or continuously but it is not employed by WSSI).

5. Turn the instrument off and remove the guard and replace the cal/transport cup on the probes.

4. END OF DAY CHECKS

Note: DO NOT CALIBRATE THE INSTRUMENT TO THE STANDARD VALUES DURING POST CALIBRATION CHECKS. Perform post calibration before cleaning up and servicing the sensor. When performing the post calibration of the system, it is extremely important that all calibration solutions are at thermal equilibrium.

Dissolved Oxygen

1. Upon returning from the field, allow the instrument to equilibrate to room temperature. Once the temperature has stabilized, add a small quantity of fresh laboratory grade (or distilled) water into the probe and cap shut. Carefully blot dry any water droplets on the membrane sensor.

3. While the probe is adjusting, obtain the barometric pressure of the laboratory and calculate the barometric pressure correction factor. (See “Correction Factor for Barometric Pressure”).

4. Once the temperature reading has stabilized (about 10 seconds between changing to the tenths place (0.1), calculate the theoretical dissolved oxygen value and multiply by the barometric pressure correction factor. Enter this into the saturated (theoretical) end of day dissolved oxygen check on the calibration log sheet. (see “How to Calculate Theoretical Dissolved Oxygen Values”)

5. Record the dissolved oxygen reading on the probe in the end of day dissolved oxygen field on the YSI Multiprobe Calibration and Post Calibration Log. If the difference between the two is less than 0.5 mg/L the instrument is in calibration. If the difference between the Saturated DO value and the instrument indicates that the instrument is not in calibration, check again the next morning to make sure that the temperature was properly equilibrated. If the difference is still greater than 0.5 mg/L the data collected during the sampling event is suspect and should be flagged. Additionally, the instrument should not be utilized until more extensive cleaning/maintenance is conducted and the instrument calibrates well.

Specific Conductance

Note: Readings are most accurate when they lie within the calibrated range. Determine the expected range of values in the field prior to calibration.

1. Rinse the sensors twice with a small portion of the specific conductance standard, discarding the rinse each time.

2. Fill calibration cup with fresh standard solution and screw on cal/transport cup making sure that there are no bubbles in the cup.

3. Watch the specific conductance readings until they have stabilized.

4. Record the reading on the YSI Multiprobe Calibration and Post Calibration Log.

5. Compare the displayed value to the standard value and calculate the difference. If the difference is less than ±10% of 50,000 µs/cm standard then the instrument is in calibration. If the instrument is not in calibration, check again the next morning to make sure that the temperature was properly equilibrated. If the difference is still out specification, the data is suspect and should be flagged. Additionally, the YSI should not be utilized for that parameter until it has an extensive cleaning/maintenance.

pH

1. Rinse twice with a small amount of pH 7.0 buffer saved from previous calibrations to saturate the sensors. Discard the buffer after each rinse.

2. Fill cup with Fresh pH 7.0 buffer sufficient to cover the sensor.

3. Allow two minutes for thermal equilibrium. Record the pH value displayed in the YSI Multiprobe Calibration and Post Calibration Log.

4. Discard the 7.0 buffer used to do the end of day check down the drain.

5. Flush the calibration cup and sensors thoroughly twice with laboratory grade (or distilled) water.

6. Rinse the cup and sensors twice with a small amount of pH 10.00 or pH 4.00 buffer.

7. Fill the calibration cup with FRESH pH 10.00 or pH 4.00 buffer to cover the sensor and wait for the instrument to equilibrate.

8. Record the pH value displayed in the YSI Multiprobe Calibration and Post Calibration Log.

9. Replace the storage cup.

10. Compare the displayed values to the standard values. If the difference between the standard utilized and the value displayed is ± 0.2 units the pH is in calibration. If the difference indicates that the instrument is not in calibration, check again the next morning to make sure that the temperature was properly equilibrated. If the difference is still greater than 0.2 units the data is suspect and should be flagged. Additionally, the YSI should not be utilized for that parameter until it has an extensive cleaning/maintenance.

How to Calculate Theoretical Dissolved Oxygen Values (obtained from DEQ standard operating procedures)

Proper calibration of Dissolved Oxygen (DO) probes is important to collect accurate data. An easy way to see if a probe is calibrated correctly is to compare the probe's results against the theoretical DO value. This DO value is dependent on temperature and barometric pressure.

DO Level Based on Temperature

The top table on the attached chart allows users to find the DO level based on temperature. The top and side axis of the table corresponds to the temperature that the probe is reporting. The intersection of these two axes displays the DO reading. Write this number down to start calculating the theoretical DO level.

Correction Factor for Barometric Pressure

Barometric pressure measures how much atmosphere is pressing down on a surface. Weather systems and elevation above (or below) sea level can change this value. The bottom table of the attached chart will help compensate for these changes in pressure. Dissolved oxygen probes normally show pressure in millimeters of mercury (**mmHg**) or millibars (**mBar**).

Having a barometer on hand is a good way to get pressure data. A weather station can also provide this information. Websites such as www.wunderground.com are useful to find nearby stations. Please note that most barometers and weather stations report pressure in inches of mercury (**inHg**).

Note: Using Weather Station Barometric Pressure Readings

Weather stations standardize barometric pressure readings to make it appear as if the station is at sea level. To account for this, subtract the barometric pressure reading by 1.01 inHg per 1,000 feet in elevation of the weather station. This final value is known as **absolute barometric pressure (ABP)**.

Example: Find the absolute barometric pressure of a station located 222 feet above sea level that reported 30.12 inHg.

$$30.12\ \text{inHg} - \frac{1.01\ \text{inHg}}{1000/\ 222\ \text{feet}} \Rightarrow 30.12 - \frac{1.01}{4.50} \Rightarrow 30.12 - 0.22 = 29.90\ \text{inHg ABP}$$

Once identifying local pressure, use the bottom table to find the proper correction factor to use. The formulas at the bottom of the chart will help in converting inHg barometric pressure reading into mBar (or mmHg) used by the probe. Use this value to find the correction factor to use in the final calculation.

Example: A barometric pressure of 970 millibars you would use a correction factor of 0.96 (second column, bottom row).

Theoretical DO Calculation

To find the theoretical DO value, use the following formula.

Theoretical DO = (DO level based on temperature) x (barometric pressure correction factor)

Example: If a probe had a temperature of 18.4 C and the barometric pressure was 970 mBar, the theoretical DO value would be 9.00 mg/L (9.37mg/L x 0.96 correction factor

DEQ Dissolved Oxygen Calibration Sheet

Directions- To calculate the theoretical DO saturation level, multiply the O2 concentration value (found in the top chart) by the barometric pressure correction factor (bottom chart).

Temp in ^{O}C	O_2 concentrations in mg/l									
	0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
5	12.75	12.71	12.68	12.65	12.61	12.58	12.55	12.52	12.48	12.45
6	12.42	12.39	12.36	12.32	12.29	12.26	12.23	12.2	12.17	12.14
7	12.11	12.08	12.05	12.02	11.99	11.96	11.93	11.9	11.87	11.84
8	11.81	11.78	11.758	11.72	11.69	11.67	11.64	11.61	11.58	11.55
9	11.53	11.5	11.47	11.44	11.42	11.39	11.36	11.33	11.31	11.28
10	11.25	11.23	11.2	11.18	11.15	11.12	11.1	11.07	11.05	11.02
11	10.99	10.97	10.94	10.92	10.89	10.87	10.84	10.82	10.79	10.77
12	10.75	10.72	10.7	10.67	10.65	10.63	10.6	10.58	10.55	10.53
13	10.51	10.48	10.46	10.44	10.41	10.39	10.37	10.35	10.32	10.3
14	10.28	10.26	10.23	10.21	10.19	10.17	10.15	10.12	10.1	10.08
15	10.06	10.04	10.02	9.99	9.97	9.95	9.93	9.91	9.89	9.87
16	9.85	9.83	9.81	9.79	9.76	9.74	9.72	9.7	9.68	9.66
17	9.64	9.62	9.6	9.58	9.56	9.54	9.53	9.51	9.49	9.47
18	9.45	9.43	9.41	9.39	9.37	9.35	9.33	9.31	9.3	9.28
19	9.26	9.24	9.22	9.2	9.19	9.17	9.15	9.13	9.11	9.09
20	9.08	9.06	9.04	9.02	9.01	8.99	8.97	8.95	8.94	8.92
21	8.9	8.88	8.87	8.85	8.83	8.82	8.8	8.78	8.76	8.75
22	8.73	8.71	8.7	8.68	8.66	8.65	8.63	8.62	8.6	8.58
23	8.57	8.55	8.53	8.52	8.5	8.49	8.47	8.46	8.44	8.42
24	8.41	8.39	8.38	8.36	8.35	8.33	8.32	8.3	8.28	8.27
25	8.25	8.24	8.22	8.21	8.19	8.18	8.16	8.15	8.14	8.12
26	8.11	8.09	8.08	8.06	8.05	8.03	8.02	8	7.99	7.98
27	7.96	7.95	7.93	7.92	7.9	7.89	7.88	7.86	7.85	7.83
28	7.82	7.81	7.79	7.78	7.77	7.75	7.74	7.73	7.71	7.7
29	7.69	7.67	7.66	7.65	7.63	7.62	7.61	7.59	7.58	7.57
30	7.55	7.54	7.53	7.51	7.5	7.49	7.48	7.46	7.45	7.44

Barometric Pressure Correction factor:

mmHg (mBar)	Corr. Factor	mmHg (mBar)	Corr. Factor	mmHg (mBar)	Corr. Factor	mmHg (mBar)	Corr. Factor
775-771 (1033-1028)	1.02	750-746 (1000-995)	0.987	725-721 (967-961)	0.953	700-696 (934-928)	0.92
770-766 (1027-1021)	1.014	745-741 (994-988)	0.98	720-716 (960-955)	0.947	695-691 (927-921)	0.914
765-761 (1020-1014)	1.007	740-736 (987-981)	0.973	715-711 (954-948)	0.94	690-686 (920-915)	0.907
760-756 (1013-1008)	1	735-731 (980-975)	0.967	710-706 (947-941)	0.934	685-681 (914-908)	0.9
755-751 (1007-1001)	0.993	730-726 (974-968)	0.96	705-701 (940-935)	0.927	680-676 (907-901)	0.893

Convert inHg into mmHg → **mmHg = inHg x 25.4**
Convert inHg into mBar → **mBar = inHg x 33.864**

YSI Multiprobe Calibration and Post Calibration Log

Multiprobe Calibration and Post Cal Log					Group ID				Probe Model					Probe #	
	Date	Time	Temp C	B.P. (mmHg)	DO Reading (mg/L)	Theor. DO (mg/L)	Cal DO (mg/L)	pH 4	pH 7	pH 10	Cond (umohms)	Membrane Changed (Y/N)	Run ID	INIT	Comments
Calibration															
Post-Check															
Calibration															
Post-Check															
Calibration															
Post-Check															
Calibration															
Post-Check															
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Calibration															
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Additional Comments:															