THE ACADEMY
OF NATURAL SCIENCES
of DREXEL UNIVERSITY

Delaware River Watershed Initiative

Coordinated Monitoring Plan for the Subwatershed Clusters

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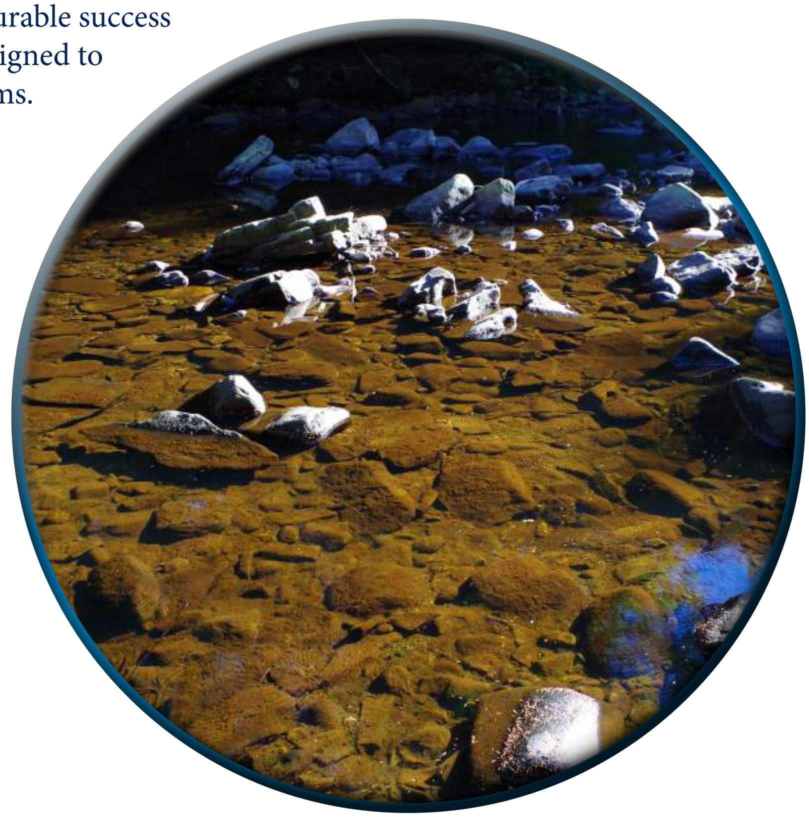
I. THEORETICAL APPROACH

This report outlines the in-stream monitoring plans for the Delaware River Watershed Initiative (DRWI) in each of its eight designated subwatershed clusters. It includes the monitoring activities undertaken by funded groups working in specific clusters, as well as the monitoring done by the Academy of Natural Sciences of Drexel University (ANS) with additional assistance of Stroud Water Research Center (SWRC). ANS will characterize in-stream conditions throughout the subwatershed clusters, assess the conditions of rivers and streams proximate to the proposed projects and control sites, and coordinate data collection by the cluster groups.

Researchers at ANS have worked closely with SWRC and cluster groups to design monitoring protocols and plans that will be useful in evaluating the success of the DRWI. These plans have been developed and are being refined by asking the following questions: What do we hope to change with this part of the Initiative? How do we expect these changes to connect within the system and extend outside the local system? Can this work produce ideas and practices that can be applied in other areas or different disciplines? Once we set the initial scope of the work and the anticipated outcomes, we developed monitoring plans to assess conditions before and after project implementation in order to provide data for measuring the nature and degree of change. These data can inform practitioners on the amount of time required to see changes, the magnitude of the change, the success or effectiveness of the approach and the connection with the theoretical foundation. Measurable success is a goal for any investment and the information obtained can be used to shape methods, refine theories and build partnerships.

Within the field of Restoration Ecology, measurable success is still a relatively new addition to projects designed to restore the structure and function of ecosystems. Lake (2001) wrote about a need to sufficiently plan and monitor stream restoration projects in addition to reporting on them to inform future work, and called restoration ecology a relatively new discipline. Palmer and colleagues (2005) gave guidelines for assessing whether restoration actions have their intended effect on the ecosystem. Although monitoring and experimental design of restoration projects have improved in the last decade, the results of these projects are still not expected to be detected in the near future or even decades from now. As one example, a riparian buffer restoration by SWRC implemented twelve years ago is beginning to show change but not full ecosystem recovery.



THEORETICAL APPROACH

Important questions which will require monitoring to inform practitioners on the success of the DRWI include: What are the effects of Agricultural Best Management Practices and Stormwater Control Measures on nearby streams receiving runoff? How are streams changing in the short- and long-term? How significant is the change in the whole ecosystem and its components? What is the rate of change and what is the lag time before the ecosystem is considered "restored" to natural conditions? Which types of projects are most effective in improving the physical and biological conditions in aquatic ecosystems?

By answering these and many other questions, the actions proposed within the DRWI have the capacity to influence the nature of restoration and conservation actions focused on improving and maintaining the integrity of aquatic ecosystems. The potential contributions to these fields result from the projects' collaborative nature, local focus, foundation on sound theories and relation with data to describe past, current and future ecological conditions of the Delaware River Basin and surrounding landscape.

Three types of sites are included for monitoring: integrative, project and control sites. Integrative sites were sampled in 2013, and more sites of this type may be added for small to medium tributaries. Project sites will be sampled as project areas are defined and each site will be visited once or twice in 2014, 2015 or 2016 as projects are awarded funding. Control sites will be sampled once or twice in 2014, 2015 or 2016 to coincide with project sampling. Several sites in each of these three categories will be visited twice during the grant period 2014-2017 to provide data on interannual variability. Periodic monitoring is recommended to continue after the grant period, with a minimum frequency of once every 5 years to continue to track ecosystem status and compile a time series of data for showing potential ecosystem response to the actions of the Delaware River Watershed Initiative over the long-term.

II. STUDY DESIGN

Integrative sites

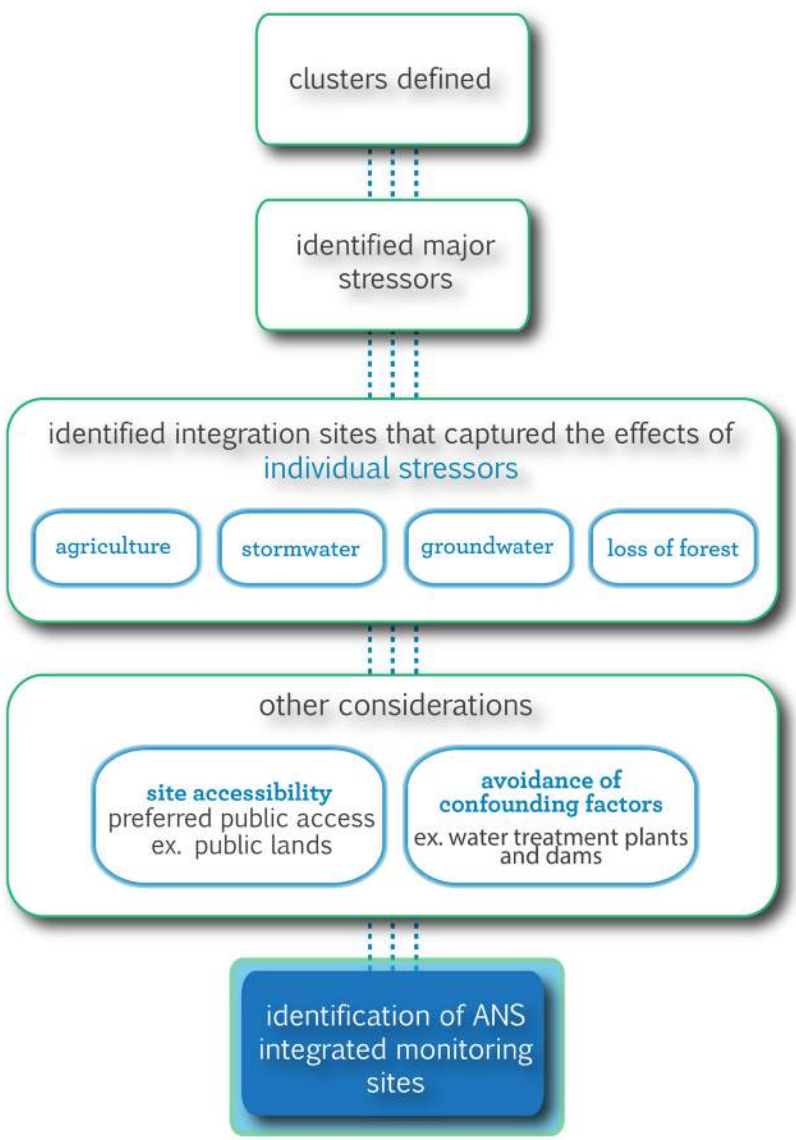
Once the subwatershed clusters were defined, sites were selected to characterize "typical" conditions within the clusters. The characteristics of these sites are shown on Figure 1 and their locations are described in Appendix I. The full set of biological indicators were sampled from these sites in 2013 and are planned to be sampled again in 2015. Water chemistry will be analyzed at integrative sites on a quarterly basis for three years. Integrative sites were chosen with the following criteria:

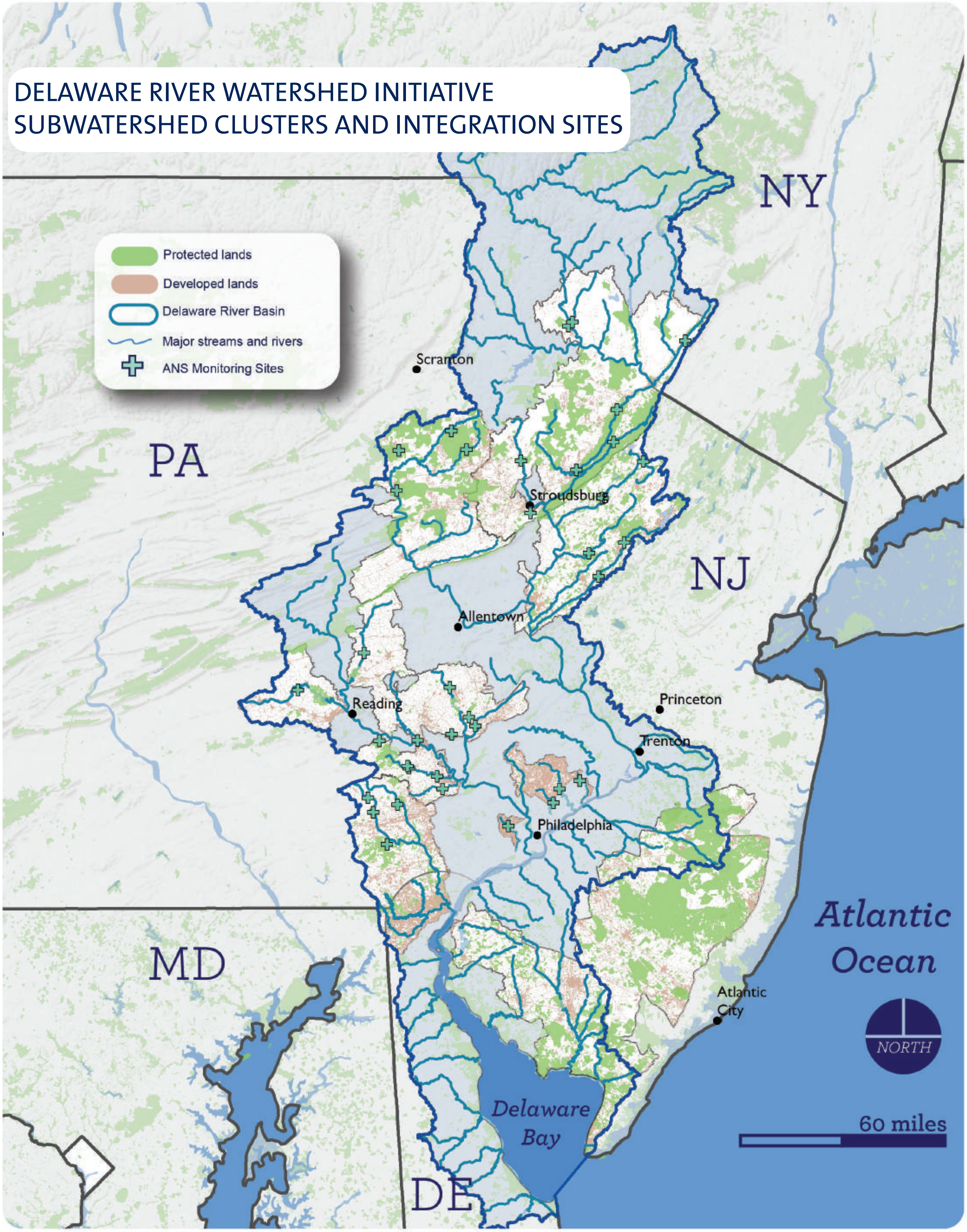
- The sites were chosen to encompass significant parts of individual subdrainages, thereby integrating land use/land cover
- The sites are located in a subwatershed with stressors typical of the area; agricultural or urban land in a percentage that is similar to the overall percentage in the subwatershed.
- The subwatersheds chosen contribute significantly to the amount of water resources; streams are typically 3rd order or larger, and very small tributaries are avoided.
    - For most sites in agricultural and protection areas, very large streams were avoided so that point sources of urban input were not captured.
- As many major tributaries in each cluster as possible are included.
    - In large clusters with many streams, such as the Poconos cluster, a variety of streams were selected, although it was not possible to cover as many major tributaries as in smaller clusters.
    - Larger streams were chosen to reflect general conditions of the watershed, while downstream sites were avoided so that urban input signals were not captured.
- Few known, significant point source inputs were identified upstream using GIS information and expert knowledge, for example:
    - Site must be far enough downstream of a town to avoid signaling other point source inputs (storm-induced sewage overflow),
    - If point sources were observed during site scouting, site would be relocated,
    - In two cases, sites were located downstream of a point source considered typical for the region (Musconetcong River and West Branch Brandywine Creek).
- Sites are on public land, when possible, to ensure access in the future. When necessary, sites are placed on private land and landowners are contacted to request permission
- The site has relatively easy access for field crews, for reasons of efficiency and safety.

STUDY DESIGN

The goal of the Delaware River Watershed Initiative is to ensure sufficient clean water through healthy watesheds in the Delaware Basin and the region of Kirkwood Cohansey Aquifer. Two ways of defining watershed quality are: 1) ability of watershed to produce high downstream water quality; 2) statistical average of quality within subwatersheds of the larger area. The larger integrative sites address the former. In order to address the latter, ANS will identify a subset of integrative sites located in smaller tributaries in clusters where description of the typical habitat characteristics and corresponding biota is necessary. If smaller tributaries of the subwatershed cluster have been left out from the list of integrative, project and control sites and appear to be important to completing the picture of chemical, habitat and biological characterization of cluster streams, additional sites will be included in 2015.

INTEGRATED MONITORING SITE SELECTION METHODOLOGY




DELAWARE RIVER WATERSHED INITIATIVE
SUBWATERSHED CLUSTERS AND INTEGRATION SITES
Protected lands
Developed lands
Delaware River Basin
Major streams and rivers
ANS Monitoring Sites
NY
PA
NJ
MD
DE
Scranton
Stroudsburg
Allentown
Reading
Princeton
Trenton
Philadelphia
Atlantic City
Atlantic Ocean
Delaware Bay
NORTH
60 miles

STUDY DESIGN

Project Sites

As grants are awarded to cluster groups for restoration and preservation projects, ANS is working closely with all project participants to identify where cluster monitoring partners can contribute resources to capture the conditions around each project site.

- For agricultural BMP projects, the BACI experimental design (Before- After, Control-Impact (Stewart-Oaten, 1986)) will be used.
  - Although this approach requires a significant amount of resources (in practice twice as many monitoring sites compared to downstream only), it provides information on stream communities upstream of the project (control), where the conditions of the area will be unchanged by the project as well as downstream, where the project is intended to have a measurable change ("impact").
  - Both upstream and downstream sites are monitored before and after project implementation to gauge the relative response in the downstream reach.
  - The use of an upstream control site for comparison is important for considering any interannual variability in in-stream communities and avoiding misidentifying ecosystem response to the project actions when differences in biota over time or space are due to weather, climate or other factors.
  - Locating an upstream control site as close to the project as possible is optimal, in a stream segment with similar characteristics to the downstream site.
  - These control sites have similar land use percentages and geology as the impact sites due to their proximity. Incorporating additional control sites located in other locations in the cluster will strengthen the analysis of project action effect by increasing sample size, and provide insurance against future changes that may affect the upstream control site.
  - Upstream controls may not be feasible in some situations, e.g., where there are significant changes in topography, habitat, etc., upstream of the project site; in these, cases negative control sites on other streams (see next section) will be used
  - Upstream control sites are not appropriate where the restoration is expected to change upstream conditions; for example, dam removal could change upstream fish assemblages; we will evaluate these concerns for the specific restoration practices, although they may not be an issue for the types of restorations currently planned.
  - Additional control sites will be identified to provide additional information on the effects of the BMPs.

STUDY DESIGN

- In preservation clusters, only downstream sites will be monitored. Controls may be temporal (multiple baseline samples at the same site) or sites on other streams will be used. Once parcels are identified, the plausibility of sampling downstream of all parcels will be evaluated. Current cluster monitoring plans do not cover all land acquisitions, leaving a very large number of sites to be sampled by ANS. Options for addressing this problem include:
  - Choosing certain land acquisition sites to monitor only once, with future sampling events recommended after the grant period,
  - Choosing a subset of ecological indicators to sample at certain land acquisition sites to monitor as many sites downstream as possible with this reduced subset of indicators,
  - Focusing monitoring on sites providing a range of land areas and characteristics for studying the effects of land conservation on water quality and omitting sites with less representative characteristics or
  - Where acquisitions are clustered in a single subwatershed, single stations may be relevant to a number of individual acquisitions.

STUDY DESIGN

Control sites

Control sites will be used to compare with cluster and project sites and have the potential to add to the statistical rigor of future analyses of the results of projects. Using upstream control sites in Before, After, Control, Impact (BACI) design will offer valuable information on local conditions. By adding control sites located in other parts of the watershed, we add information as well as assurance that if conditions at some control sites change, we will still have data at another, unchanged control site. This increases the likelihood of demonstrating change compared with areas not addressed by projects through this program.

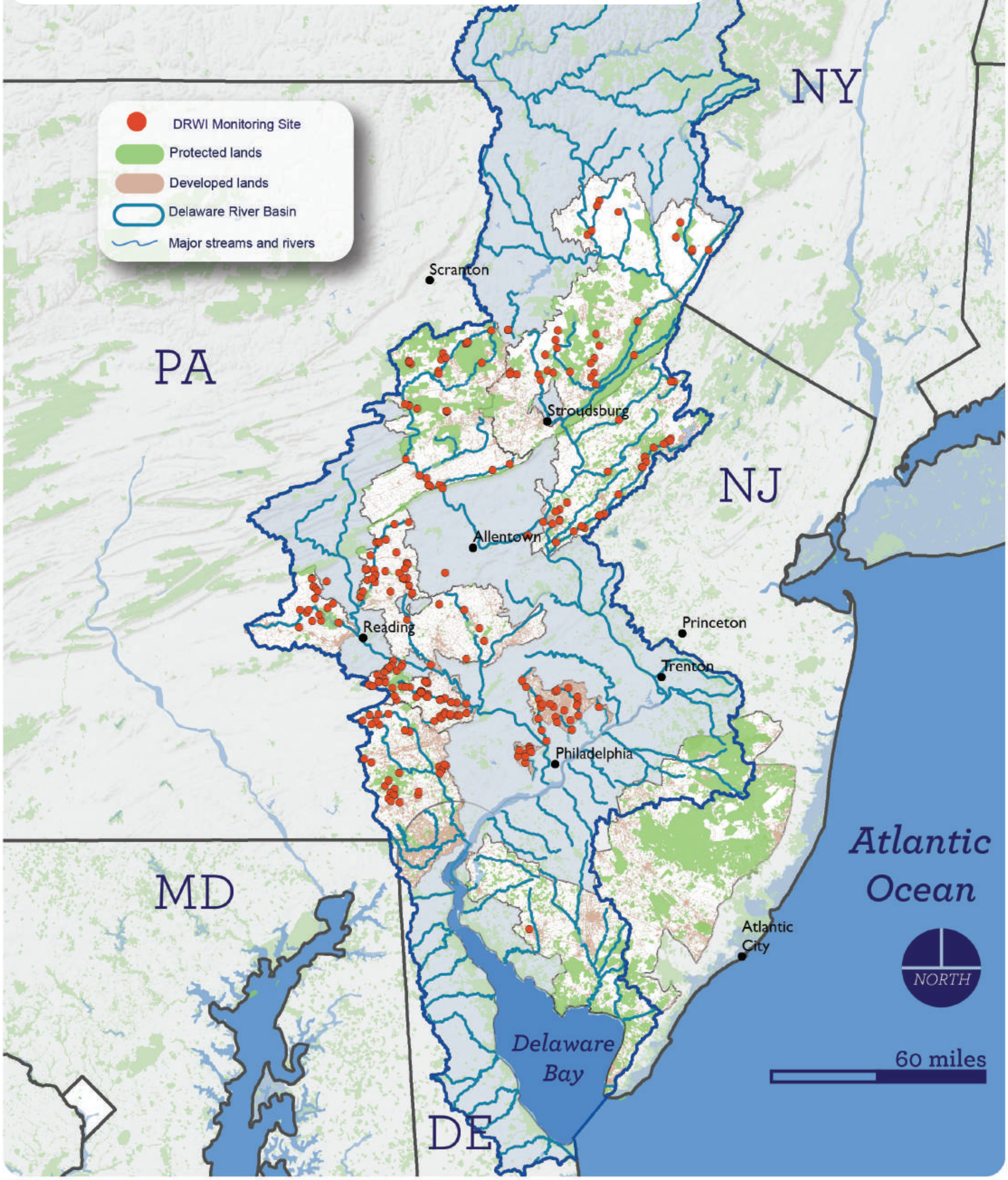
Control sites are being identified as the locations of projects are communicated with ANS. The Stream Hiker software developed and adapted by researchers at ANS will be tailored to identify these sites based on whether they are located in restoration or preservation project areas.

- Each set of project-control sites will have similar geology, drainage areas and other characteristics not related to land use.
- For active restoration projects (agriculture and storm water), both negative and positive controls on other streams will be designated.
- Negative controls are sites where no restoration is done ("no treatment" in statistical terms; similar to upstream sites for the upstream/downstream before/after (BACI) design).
- Positive controls are sites where effective restoration has been done ("treatment applied;" ideally, these would be areas where a set of known, state-of-the-art techniques had been successfully applied.
    - It is possible that are no such sites for the types of restoration activities planned here; if these sites are not found, sites in watersheds without these specific stressors will be considered as representing the benchmark for assessing the magnitude of restoration.
    - For example, positive controls for storm water sites could be sites in areas where storm water had been controlled during initial development.

STUDY DESIGN

- For protection areas, negative controls will be sites on other streams without development. To test for regional changes in watershed conditions, a single site or group of sites may serve as controls for a number of protection activities.
- No positive controls (i.e. other known conserved areas) will be designated for land protection areas because of the uncertainty of land development potential at candidate control sites; the consequences of not protecting areas will be assessed using the extensive literature on effects of development and by modeling.
- To add to the amount of data available on water quality before and after land protection, sampling may be done during multiple years to provide more baseline information on natural variability.
- For each cluster, appropriate land use percentages for control sites will be determined and will become the last criterion for control site selection in Stream Hiker.
- The number of control sites will be determined by the number and type of restoration and protection activities; for example, a smaller number of sites may serve as controls for a number of restoration or protection sites.
- Control sites should be located within the Delaware Basin, but in exceptional cases may be located in nearby drainages.

DELAWARE RIVER WATERSHED INITIATIVE SUBWATERSHED CLUSTERS AND ALL MONITORING SITES



SAMPLING PROTOCOL, ALL CLUSTERS

Monitoring is being performed by ANS and SWRC as well as by other groups working throughout the clusters. These groups range from professionals in stream ecosystem science to local watershed groups. The combination of cluster group monitoring and the work of ANS and SWRC is designed to maximize spatial and temporal coverage as well as the amount and types of data collected, and to function as an efficient, complete monitoring plan. To ensure compatibility of data, ANS held preliminary meetings regarding sampling protocols, distributed guidelines for sampling by cluster monitoring groups, has organized meetings in 2014 that will be repeated annually to discuss monitoring, and coordinates quality control on protocols as well as a subset of samples. At some sites, cluster groups will perform most monitoring when these partners have the capacity and expertise to perform sampling comparable to ANS and SWRC. However, even in clusters with this type of partner, ANS and SWRC will monitor additional control sites. In most cases, either ANS or SWRC will visit the same sites as cluster monitoring partners to sample those sets of indicators that are not being sampled by cluster groups. Where working together results in greater efficiency, monitoring by one group or the other at given times will be done: for example, cluster monitoring partners will help collect water samples to be analyzed by ANS laboratories—this increases the spatial and temporal reach of all partners by increasing collaboration and reducing travel time. The number of sites sampled will depend on the number of projects developed in each cluster. In addition, some volunteer citizen groups will be monitoring area streams using a refined protocol. Training citizen scientists to perform stream monitoring engages the community in this work and raises awareness about the conditions of waterways near where they live. At the same time, data collected by citizens will meet a second tier of quality standards so these data can also be used to assess stream conditions.

SAMPLING PROTOCOL, ALL CLUSTERS

Indicator sets

Water chemistry, fish, salamanders, aquatic macroinvertebrates, algae, habitat, as well as land use and other spatial data will be collected from sites to give an overall picture of ecosystem structure and function as they relate to landscape variables and especially human activities. This approach is essential to detecting how different in-stream biota respond to stressors caused by human activities and projects, including land protection, urban and agricultural uses and restoration actions. Different biota respond differently to stressors; by collecting data on multiple groups of biota we will tell a more complete story of ecosystem response to the actions within the Delaware River Watershed Initiative. **Table 1** shows the results of a European study on the response of different organism groups to stressors(Herring and colleagues, 2006). A recent study by researchers at ANS and the NJ DEP shows that a combination of fish and macroinvertebrate assemblages describes ecosystem integrity of streams in this area better than either indicator group along (Flinders and colleagues, 2008). Analysis of water chemistry alone can either over exaggerate or fail to detect ephemeral changes from brief pollution events. However, the biota in a given area provides information on year-round water and habitat quality. Different types of living organisms are used to provide the most information on the ecosystems' structure and function, from primary producers to high level consumers, pollution sensitive to pollution tolerant biota, and creatures with strict habitat requirements such as water temperature, oxygen levels and flow. By compiling this information, research can be designed to understand which stressors (or pristine conditions) contribute most to ecosytem status and how the actions within this program address these stressors.

SOME BIOLOGICAL INDICATORS OF THE DELAWARE RIVER WATERSHED

Acroneuria sp.

Psepheniidae sp.

Merismopedia glauca

Salvelinus fontinalis

SAMPLING PROTOCOL, ALL CLUSTERS

Table 1 a-e

AQEM multiple organism groups and stressor gradients: Correlation analyses of stressors and organism metrics. max r^2: the maximum r^2 of all metrics significantly correlating to a stressor gradient; 75 perc: the 75th percentile of the r^2 values of all metrics significantly correlating to a stressor gradient; share sg: the share of metrics significantly correlating to a stressor gradient, in relation to the total number of metrics used for the organism group (from Hering and colleagues, 2006). r^2 indicates how well the model fits the data; 1 would be a perfect fit, but in studies such as this, values around 0.2 are acceptable, and higher numbers are better, as shown by the size of the circles.

Legend

Correlation strength	% of metrics correlating
r^2 = 0.2–0.4	20–40%
r^2 < 0.6	>40–60%
r^2 < 0.8	>60–80%
r^2 < 1.0	>80–100%

Table 1a: Eutrophication Methods

	No sites	Diatoms			Macrophytes			Invertebrates			Fish		
		max r^2	75 perc	share sg	max r^2	75 perc	share sg	max r^2	75 perc	share sg	max r^2	75 perc	share sg
All mountain streams	87	0.50	0.35	85.2	0.45	0.27	17.2	0.49	0.30	90.6	0.31	0.14	60.7
All lowland streams	98	0.67	0.59	88.9	0.30	0.20	20.7	0.24	0.11	59.4	0.22	0.10	21.4
Lowland streams U15 U23	25	0.73	0.47	81.5	0.40	0.30	6.9	0.37	0.30	53.1	0.58	0.47	32.4
Lowland streams D03 K02	21	0.75	0.41	37.0	0.82	0.78	55.2	0.37	0.35	6.3	0.69	0.42	17.9
Lowland streams S05 S06	27	0.84	0.73	77.8	0.73	0.62	51.7	0.72	0.45	28.1	0.41	0.25	17.9
Lowland streams O02	25	0.24	0.24	3.7	0.45	0.42	13.8	0.47	0.44	18.8	0.45	0.35	14.3

Table 1b: Land Use Metrics

	No sites	Diatoms			Macrophytes			Invertebrates			Fish		
		max r^2	75 perc	share sg	max r^2	75 perc	share sg	max r^2	75 perc	share sg	max r^2	75 perc	share sg
All mountain streams	87	0.37	0.24	85.2	0.36	0.20	62.1	0.31	0.23	84.4	0.16	0.09	46.4
All lowland streams	98	0.38	0.25	88.9	0.25	0.15	27.6	0.12	0.10	43.8	0.18	0.15	25.0
Lowland streams U15 U23	25	0.00	0.00	0.00	0.25	0.19	17.2	0.00	0.00	0.00	0.20	0.19	14.3
Lowland streams D03 K02	21	0.30	0.24	37.0	0.21	0.20	10.3	0.39	0.35	12.5	0.40	0.40	17.9
Lowland streams S05 S06	27	0.81	0.62	70.4	0.58	0.46	48.3	0.66	0.38	21.9	0.40	0.22	28.6
Lowland streams O02	25	0.56	0.40	70.4	0.38	0.38	13.8	0.44	0.41	31.3	0.20	0.20	3.6

SAMPLING PROTOCOL, ALL CLUSTERS

Table 1c: Reach Scale Hydromorphology

	No sites	Diatoms						Macrophytes						Invertebrates						Fish					
		max r^2		75 perc		share sg		max r^2		75 perc		share sg		max r^2		75 perc		share sg		max r^2		75 perc		share sg	
All mountain streams	87		0.09		0.07		12.1	•	0.25		0.19	●	48.2	•	0.23		0.13	●	50.0		0.13		0.12	•	28.6
All lowland streams	98		0.00		0.00		0.00		0.12		0.10	●	44.8	•	0.26		0.16	●	43.8		0.17		0.15	●	46.4
Lowland streams U15 U23	25		0.00		0.00		0.00		0.00		0.00		0.00	•	0.35	•	0.35		3.1		0.00		0.00		0.00
Lowland streams D03 K02	21		0.00		0.00		0.00		0.40	•	0.38	•	27.6	●	0.45	•	0.38	•	28.1	●	0.42	•	0.37	•	21.4
Lowland streams S05 S06	27		0.00		0.00		0.00	•	0.20		0.19		10.3	•	0.20	•	0.20		6.3	•	0.24	•	0.20	•	28.6
Lowland streams O02	25	●	0.41	•	0.25	•	25.9	•	0.30	•	0.27		6.9	●	0.51	●	0.41	•	37.5	●	0.46	•	0.35	•	28.6

Table 1d: Microhabitat Scale Hydromorphology

	No sites	Diatoms						Macrophytes						Invertebrates						Fish					
		max r^2		75 perc		share sg		max r^2		75 perc		share sg		max r^2		75 perc		share sg		max r^2		75 perc		share sg	
All mountain streams	87	•	0.20		0.14	●	51.9	•	0.20		0.16	•	31.0	•	0.33		0.18	⬤	62.5		0.16		0.14	•	32.1
All lowland streams	98	•	0.36	•	0.27	●	47.1	•	0.31	•	0.23	⬤	72.4	•	0.38	•	0.21	•	37.5		0.19		0.12	•	35.7
Lowland streams U15 U23	25		0.76	●	0.49	●	55.6	⬤	0.70	⬤	0.65	•	24.1	•	0.35	•	0.35		3.1		0.00		0.00		0.0
Lowland streams D03 K02	21		0.00		0.00		0.0		0.00		0.00		0.0		0.62	●	0.45		12.5	⬤	0.64	●	0.44	•	21.4
Lowland streams S05 S06	27		0.18		0.18		3.7	●	0.41	•	0.34	•	20.7	•	0.30	•	0.28		18.8	•	0.29	•	0.27	•	21.4
Lowland streams O02	25	•	0.27	•	0.27		3.7	•	0.24	•	0.24		6.9	•	0.33	•	0.31	•	34.4	●	0.45	●	0.40		7.1

Table 1e: General Degradation Metrics

	No sites	Diatoms						Macrophytes						Invertebrates						Fish					
		max r^2		75 perc		share sg		max r^2		75 perc		share sg		max r^2		75 perc		share sg		max r^2		75 perc		share sg	
All mountain streams	87		0.12		0.06	•	22.2	•	0.25	•	0.21	⬤	69.0	•	0.29		0.14	⬤	62.5		0.12		0.07		17.9
All lowland streams	98	•	0.34	•	0.29	⬤	88.9	•	0.21		0.17	⬤	82.8	•	0.25		0.16	●	56.3	•	0.29	●	0.25	⬤	64.3
Lowland streams U15 U23	25		0.18		0.18	•	22.2	•	0.28	•	0.26		6.9	•	0.25	•	0.22		9.4	•	0.26	●	0.26		14.3
Lowland streams D03 K02	21	•	0.21	•	0.21		3.7	●	0.42	•	0.39	●	48.3	●	0.52	●	0.49	•	25.0	●	0.53		0.38	●	42.9
Lowland streams S05 S06	27	⬤	0.69	●	0.52	⬤	74.1	●	0.57	●	0.59	•	20.7	●	0.44	●	0.43		15.6		0.16	●	0.16		3.6
Lowland streams O02	25	●	0.54	•	0.34	⬤	66.7	•	0.32	•	0.27	•	31.0	●	0.56	●	0.49	●	53.1	•	0.38		0.30	•	35.8

SAMPLING PROTOCOL, ALL CLUSTERS

Two-tiered Approach

Monitoring throughout the clusters is separated into two Tiers: Tier 1 is the level at which SWRC and ANS sample. Tier 2 follows the protocols developed by the New Jersey Department of Environmental Protection's Volunteer Monitoring Program. The data collected using both tiers will thus be consistent throughout the subwatershed clusters. The two Tiers are summarized in **Table 2**.

Table 2

Tier	Stream-side Chemistry	Laboratory Chemistry	Chemistry Parameters	Macroinvertebrate Method	Macroinvertebrate ID level
1	YSI Sonde or other probe	ANS or other designated lab	See Table 3	Surber sampler	Genus
2	Hach kit or other chemistry kit	Hach kit or other chemistry kit; non-designated lab	Fewer parameters and higher detection levels than Table 3	Kick nets	Family

Sampling for water chemistry, macroinvertebrates, algae fish and salamanders take place throughout different times of the year. Sampling season and duration are summarized below.

Sampling Seasons

	Spring	Summer	Fall	Winter
Water chemistry	Integrative sites Project sites	Integrative sites Project sites	Integrative sites	Integrative sites
Macroinvertebrates	February-April			
Algae		July-September		
Fish		May-October		
Salamanders	2013 & 2014 (methods study, before leaf fall)			

SAMPLING PROTOCOL, ALL CLUSTERS

Water Chemistry // *Tier 1*

Water samples are being collected throughout the year with a frequency adapted to the type of stressor (or lack of stressors) at each project and integrative site. Chemical parameters and detection limits are listed in **Table 3**.

- At each sampling event, a 4-liter cube of water is collected at the site and discharge is measured to calculate the loads of chemical constituents.
  - One extra sample and a "field blank" of air at the site are taken every 10 sites for quality control.
  - A portion of each water sample is filtered within 24 hours for analysis of nutrients.
  - The unfiltered water is analyzed for major ions and other variables.
  - Samples are frozen until lab analyses are performed.
- Each Integrative Site is sampled quarterly to give a picture of seasonal changes in water chemistry due to:
  - Changes in temperature and precipitation as well as related landscape processes such as autumn leaf fall entering streams,
  - Low winter temperatures and reduced in-stream metabolism,
  - Spring snowmelt and manure application to fields (and subsequent runoff),
  - Summer temperatures and increased in-stream metabolism,
  - Changes in in-stream flow throughout the year, and
  - Where relevant, quarterly samples may be storm-related.
- Monthly chemistry samples will be taken at sites where more frequent changes in water chemistry are expected due to septic system leakage and ongoing agricultural inputs from runoff and erosion.
- Timed samples will collect water during stormwater peaks of precipitation events in areas characterized with high urban and/or agricultural runoff.
  - These stormwater samples will be taken with automatic sampling devices that are triggered by increasing flow during a storm.
- Continuous monitoring of stream temperature (2013-2016) and conductivity (2014-2016) will provide information to be used in watershed models and characterize annual trends.

Water Chemistry // *Tier 2*

For Tier 2, probes such as Hach kits or Lamotte kits can be used to take streamside chemical measurements at detection levels that are higher (less accurate) than Tier 1 methods, wherein samples are analyzed in a laboratory. This approach gives citizen monitors the opportunity to see the test results right away and

SAMPLING PROTOCOL, ALL CLUSTERS

Table 3: Tier 1 Detection limits for water chemistry parameters analyzed

Ancillary Measurement	Reference Method	Detection Limit
Total Suspended Solids	SM20(1998); ANSP SOP	< 1.0 mg/L
Total Dissolved Solids	SM20(1998); ANSP SOP	3.74 mg/L
Dissolved N and P (various forms)	US EPA (1993); ANSP SOP	< 10 µg N or P/L
Total Phosphorus	US EPA (1993); ANSP SOP	< 5 µg P/L
Total Kjeldahl nitrogen (TKN)	US EPA (1993); ANSP SOP	< 100 µg N/L
Total Hardness	SM20(1998); ANSP SOP	2.00 mg/L
Sulfate	SM15(1980); ANSP SOP	1.2 mg/L
Total Alkalinity	SM20 (1993); ANSP SOP	< 1 mg/L
Bromide	ALPKEM Method; ANSP SOP	0.128 mg/L
Chloride	SM20(1998); ANSP SOP	0.61 mg/L
Na, Mg, Ca, K	ASTM D6919-03	0.07, 0.03, 0.07, 0.16 mg/L, respectively
Barium and Strontium	EPA200.8 (1998)	In Prep.

Fish // *Tier 1 only*

Fish have been found to respond to local as well as large-scale landscape characteristics. The strength of influence of factors on each of these scales must be assessed on a watershed-by-watershed basis to tailor assessment and also restoration actions to the stressors with the greatest influence and to explain natural differences in assemblages. Fish communities represent several levels of the food chain and have been found to exert heavy influences on lower trophic levels as well as being regulated by the movement of energy up the food chain. They also represent a broad range of habitat preference and pollution tolerance.

- The method used is called depletion sampling, which is typically performed by blocking a reach with nets and typically performing two or more passes with electrofishing backpacks.
    - Depletion sampling allows estimation of total abundance of different species.
    - One-pass sampling is typically used by state and federal agencies for bioassessment because the multipass sampling is more time-consuming; data are evaluated using indices which don't depend on fish abundance.
    - Depletion sampling controls for differences in catchability among different taxa and across different sites; the resulting data can provide more sensitive indicators of the condition of fish communities.
    - This difference in method is expected to result in different biotic index values derived from each method, However, data from multipass sampling are compiled for each pass so that first-pass counts can be compared to state and federal agency data.
- All fish over 25 mm total length are counted. All fish specimens are measured, except that groups of similar-sized individuals may be sub-sampled when the number of individuals is extremely high.
- Where a subsample of all fish is measured, efforts are made to avoid size-selection in measurement.
- Notes are taken on the number of diseased and anomalous individuals (excluding blackspot disease), based on external characters.
- The number of each species collected is standardized by the size of the sampling reach; the effects of various kinds of site differences (e.g., watershed drainage size, habitat conditions) can be statistically assessed to provide more precise assessments of treatment effects.
- Fish are sampled during the summer starting approximately in June and ending in October.
- Within each subwatershed cluster, samples are grouped as close as possibly temporally to avoid bias by fish growth throughout the season and recruitment to the equipment (reaching a large enough size to be caught).

SAMPLING PROTOCOL, ALL CLUSTERS

Salamanders // ANS *Tier 1 only*

Amphibians are known to include many species that are particularly sensitive to pollution and with specific habitat requirements. The existing protocols for sampling salamanders were developed by ANS for small streams in New Jersey, based on existing salamander sampling techniques. However, these protocols have not been extensively tested across a range of stream conditions (size, etc.). Therefore, a study is being performed testing and refining sampling protocols for increasing the effectiveness of using salamanders of indicators of stream ecosystem integrity. The protocol applied in 2013 and 2014 is as follows:

- Two, 20-meter transects are sampled at each site.
- Each timed sample will be taken in a 20-meter reach of stream by a crew of two for 20 minutes.
- Available cover (i.e. cobble) will be turned by hand both in the stream and within 1 m of the stream.
- Aquarium dip nets are used to aid salamander capture. All salamanders captured are identified to species (except that some larval salamanders may not be able to be identified to species level and will be identified to the lowest level possible).
- Habitat assessments are performed which characterize both riparian conditions (e.g., canopy cover) and bed composition.

SAMPLING PROTOCOL, ALL CLUSTERS

Macroinvertebrate sampling // *Tier 1*

Macroinvertebrates are commonly used as indicators of aquatic ecosystem integrity for many reasons, including the ability to detect different types of stressors and impacts on streams, their ubiquitous nature and the development of universal as well as regional protocols and analysis tools. SWRC is performing macroinvertebrate sampling for all integrative and control sites as well as project sites within three clusters. The methods used are as follows:

- A Surber sampler is used at all of the sample sites to develop a quantitative view of the macroinvertebrate communities.
  - A Surber is a 0.09 m^2 device that should be placed in a riffle area where water flow is between 0.25 and 0.8 meter per second.
- Benthic macroinvertebrates are collected in riffles with a Surber sampler (0.093 m^2, 250 μm mesh) using a quantitative composite sampling regime. Sixteen random samples will be collected at each site.
  - A composite macroinvertebrate sample is created in the field by combining four random Surber samples in a large bucket and randomly removing ¼ of the material using a quadrate splitting tool.
- In the laboratory, each composite sample is subsampled to reduce the number of macroinvertebrates examined to 200 to 300 individuals per sample (800–1200 individuals per site per year).
  - Insects, including the Chironomidae, are identified to the lowest possible taxonomic unit (usually genus or species).
  - Non-insect macroinvertebrates (e.g., oligochaetes, mollusks, nematodes) are identified to higher taxonomic levels (i.e., class or order).
- This sampling is done prior to fish, algae, amphibian sampling and habitat assessment to ensure that early emerging insects are included in samples while they are still aquatic larvae.

SAMPLING PROTOCOL, ALL CLUSTERS

Macroinvertebrate sampling // *Tier 2 Kick Sample Protocol*

Adapted from NJ DEP Volunteer Biological Assessment Manual http://www.state.nj.us/dep/wms/bwqsa/vm/docs/biological_manual_2013.pdf

The kick sampling protocol is used in streams that are too deep to be sampled with a Surber sampler, or streams with rocky, boulder-filled bottoms.

The kick seine is placed on the substrate in the riffle or run and the user stands upstream from the net. Any large rocks should be rubbed off in the stream so that anything clinging to them will be carried by the current into the net. Some of the rubbed off rocks can be used to anchor the bottom of the net down. Remaining on the upstream side of the net, the sampler gently moves the substrate using his or her boots to kick up all the remaining substrate as thoroughly as possible within a 3 foot square area upstream of the net. Once the upstream area has been thoroughly disturbed the net should be rinsed off into a bucket, making sure to check the net for any remaining clinging organisms.

Sub-Sampling

The contents of the bucket are poured into a shallow tray that has been divided into squares of equal area (the area of square, in cm, is noted) and the contents are distributed evenly on the tray. The contents of one square are removed and 100 macroinvertebrates are picked out, without discriminating for size/species/etc., and placed into sample jars container filled with 75-95% ethanol. If 100 organisms are not present in the first square, a second is taken, and so on, until 100 macroinvertebrates have been counted.

SAMPLING PROTOCOL, ALL CLUSTERS

Algae // ANS Tier 1 only

Algae have become increasingly used as indicators of nutrient enrichment and for detecting nutrient levels in streams due to the specific thresholds of some species. The California SWAMP protocol for algae (Surface Water Assessment Monitoring Protocol) is used because it specifies sampling in multiple habitats. SWAMP has been rigorously tested in Californian streams for the past decade. The multihabitat approach includes a broad diversity of microhabitats and therefore may provide a complete picture of algal communities, as compared to richest targeted habitat assessments which have been applied in the region previously. The samples are taken as habitat is assessed because of the similarities in SWAMP and WSA (see below) habitat variables. Biotic indices that have been developed for algae in mid-Atlantic drainages are being adapted for this newly applied protocol for this area by phycologists at ANS.

- Algae are collected from different areas at each of 11 transects (sides, center or at 25% of width of channel),
- Substrate and depth are measured where samples are taken,
- Algae are combined into a composite sample,
- The composite is divided into three parts to be preserved and analyzed for: diatom community, soft algae community and concentration of chlorophyll *a*.
- Sampling cannot take place after a significant scour event, defined as greater than 2" of rain during a 24-hour period, and within the 25th and 75th percentiles of flow at the nearest stream gage.

SAMPLING PROTOCOL, ALL CLUSTERS

Habitat // *Tier 1 only*

Assessment of habitat is essential for interpreting sampling results, as it provides information on local conditions and whether large or small-scale landscape stressors influence these conditions. The U.S. EPA Wadeable Stream Habitat Assessment (WSA) is being used because of its completeness and the ability to compare with agency data. The WSA combines the rapid habitat assessment developed for the EPA in 1999 by Plafkin and colleagues with the following measurements in 11 transects:

- In-stream habitat (depth, substrate, embeddedness, aquatic plants and algae),
- Channel shape,
- Streambank condition (vegetation, erosion, incision) and
- Riparian forest structure.

Other characteristics of the entire reach include:

- Channel form (straight, meandering, braided) and condition,
- Signs of pollutants (foam, films) or naturally occurring, unique conditions (tannins),
- Valley shape and stream gradient (slope),
- Visible sources of point and non-point source pollution and
- Alterations to riparian zone.

Physicochemical variables, including dissolved oxygen, specific conductance, temperature and pH are also measured within each site.

STANDARD SAMPLING PROTOCOL, ALL CLUSTERS

Other Indicators

Geomorphology will be assessed in areas where erosion is observed; bank pins and channel form surveys will be conducted to examine the amount of erosion and changes in bank stability over time.

Stormwater samples will be taken where restoration projects are expected to have an influence over stormwater quality and/or quantity.

Planning for fecal coliform testing is taking place during 2014 and 2015 by evaluating projects where this indicator is important. Part of this planning process is determining which sources of fecal coliforms should be tracked in which areas. Sampling sites are being selected for a pilot study starting in 2015 on fecal coliforms and endocrine-disrupting compounds related to livestock operations.

Edge-of-field sediment traps are being piloted in 2014 for application at other project areas. These traps are being used to determine the amount of sediment that runs off a field in relation to the amount of rain received over a 24-hour period, and can show quick response to restoration actions.

Macroinvertebrates in lentic areas (pools) near restoration projects are being sampled in 2014 to examine their use in response to agricultural activities and BMP implementation.

Quality Assurance

Internally, ANS creates documentation for field and lab procedures, which is meant to be a guide to all staff involved in sampling and processing samples. The 2013 integrative site QAPP (Quality Assurance Program Protocol) has been slightly modified for ANS monitoring and use in-house. The QAPP has been adapted for cluster monitoring groups.

CLUSTER-SPECIFIC MONITORING PLANS

Cluster groups have identified partners to monitor streams connecting to their project sites. Each cluster has unique capabilities, and their monitoring plans reflect the diversity of cluster group partners. Based on the most recent information from Implementation Plans and meetings with cluster groups, ANS has developed monitoring plans that fit together with cluster group plans to ensure full coverage of project sites with the indicators that are expected to best reflect the effects of conservation actions on their adjacent stream ecosystems.. The exact locations of some projects are still unknown; in these cases, ANS has brought together the other details available on monitoring without specific location data.

The combination of monitoring by ANS and SWRC with cluster groups serves to:

- Increase the spatial and temporal extent of sample collection,
- Increase the capacity of local volunteer and academic institutions to monitor,
- Engage community members with their local watershed and
- Provide resources for long-term commitments of groups to stream monitoring to measure the effects of conservation and restoration actions in the future

Cluster groups have developed monitoring plans to fit one of the two tiers on monitoring described in the previous section. Most cluster groups are working collaboratively with professionals within their groups as well as at ANS and SWRC to meet Tier 1 standards, although some apply Tier 2 methods for monitoring with community members.

CLUSTER-SPECIFIC MONITORING PLANS

UPPER LEHIGH

Focus/Monitoring Areas

- Lehigh River immediately downstream of confluence with Aquaschicola Creek as river crosses through Kittatinny Ridge
- Tobyhanna Creek just prior to its confluence with the Lehigh River
- Lehigh River just prior to its confluence with Tobyhanna Creek
- Lehigh River in Lehigh Gorge State Park just prior to its confluence with Sandy Run
- Lehigh River at the south end of Lehigh Gorge State Park

Cluster Group Monitoring

Water quality and aquatic communities at key locations in Upper Lehigh; pre- and post-preservation monitoring includes physical habitat assessments, water chemistry analysis and benthic macroinvertebrate and fish community surveys. This work will be done by local Moravian and Lehigh Universities as well as the Lehigh River Stocking Association, Trout Unlimited and staff at the Wildlands Conservancy. The cluster organization has chosen mainstem sites on the Lehigh and Tobyhanna to represent cumulative impacts of preserved lands in these areas.

Methods

- Physical habitat assessments according to procedures outlined by EPA: Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers.
- Chemical analysis on pH, temperature, specific conductance, dissolved oxygen, biological oxygen demand, total phosphates, nitrate, nitrite and ammonia nitrogen.
- Benthic macroinvertebrate surveys using Tier 1 protocol for the Delaware River Watershed Initiative.
- Fish surveys by electrofishing to derive Indices of Biotic Integrity.

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CLUSTER-SPECIFIC MONITORING PLANS

UPPER LEHIGH

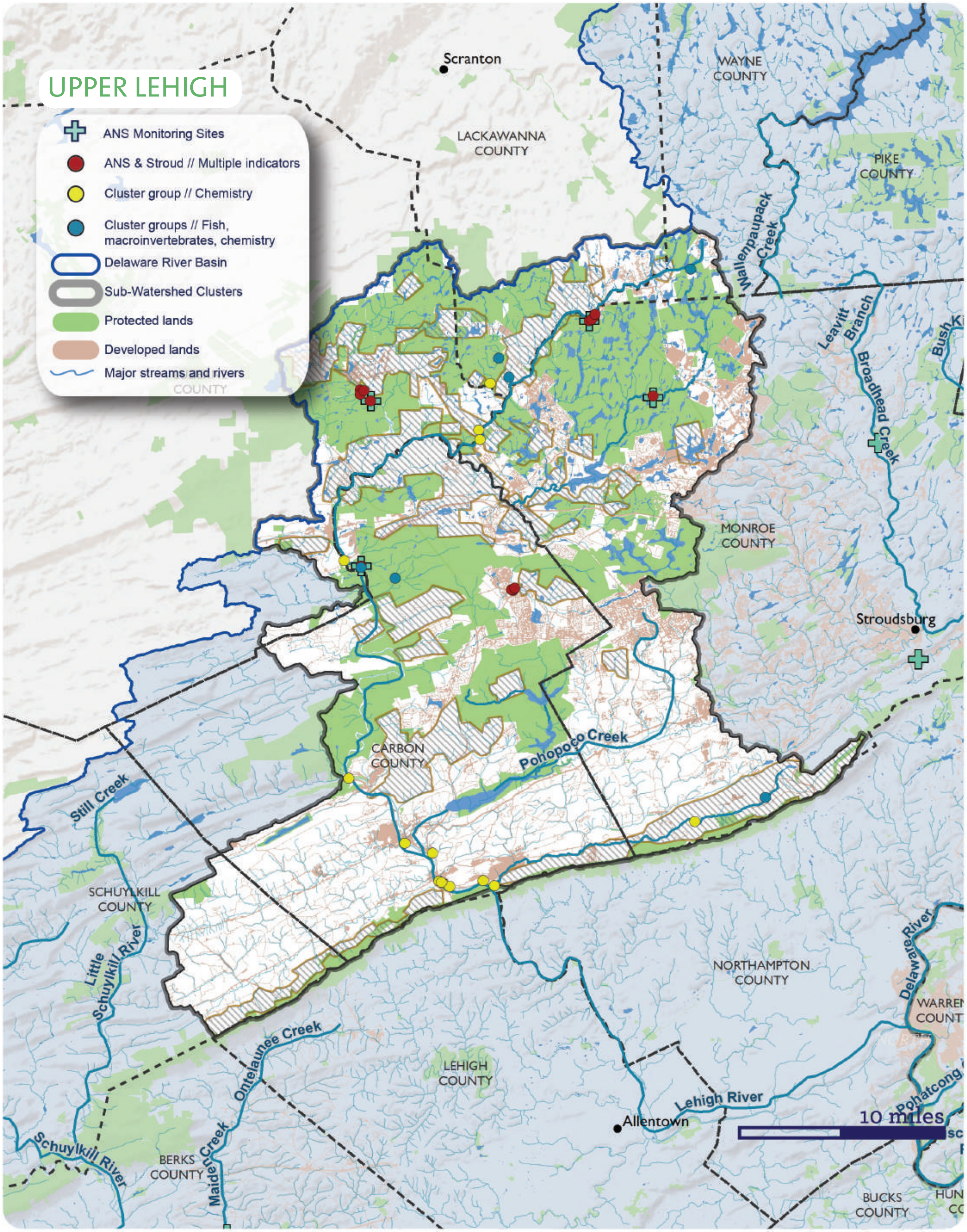
ANS Monitoring and Quality Assurance

After a preliminary meeting, ANS discussed monitoring sites closer to land preservation parcels. Currently, ANS is examining the location of parcels identified for acquisition and determining how to best monitor them. The location of the parcels can be seen on the attached Upper Lehigh cluster map (Figure 2).

Key Points

- The cluster team has agreed to use protocols used by ANS and to examine detection levels for water chemistry samples at ANS to be sure that monitoring partners apply the same levels.
- Salamanders and algae will be collected by ANS at sites throughout the cluster (downstream of projects as well as additional control sites or sampling events).
- Fish (ANS) and macroinvertebrates (SWRC) will be sampled at some control sites comparable to some project sites:
- These sites are expected to be sampled in 2014 or 2015, depending on timing of land acquisition by cluster groups and project site monitoring.
- Control sites will be defined for a set number of projects; several projects may share one control site.
- Control site selection will depend on potential for development upstream of project site as well as upstream of potential control sites

The land preservation easements obtained in this and other areas within the Initiative will provide data for assessing how the location and size of preserved and forested land parcels can contribute to high biotic integrity of nearby waterways; percent forest cover and water quality has been examined thoroughly in the literature, although definitive values are not always ubiquitously applicable. The size and location of preserved land has been examined for terrestrial ecosystem and to some extent for aquatic ecosystems, but relationships with water quality have not been well-defined. A study on the effects of land use in headwater streams on ecosystem integrity would benefit from sampling baseline conditions several times and then resampling periodically (every 2-3 years or even 5 years over the next 2-3 decades) to detect long-term trends.


UPPER LEHIGH
ANS Monitoring Sites
ANS & Stroud // Multiple indicators
Cluster group // Chemistry
Cluster groups // Fish, macroinvertebrates, chemistry
Delaware River Basin
Sub-Watershed Clusters
Protected lands
Developed lands
Major streams and rivers
Scranton
LACKAWANNA COUNTY
WAYNE COUNTY
PIKE COUNTY
Wallenpaupack Creek
Leavitt Branch
Broadhead Creek
MONROE COUNTY
Stroudsburg
CARBON COUNTY
Pohopoco Creek
Still Creek
SCHUYLKILL COUNTY
Little Schuylkill River
NORTHAMPTON COUNTY
Delaware River
Ontelaunee Creek
LEHIGH COUNTY
Lehigh River
Allentown
Pohatcong
10 miles
Schuylkill River
BERKS COUNTY
Maiden Creek
BUCKS COUNTY

CLUSTER-SPECIFIC MONITORING PLANS

POCONOS AND KITTATINNY

Focus/Monitoring Areas

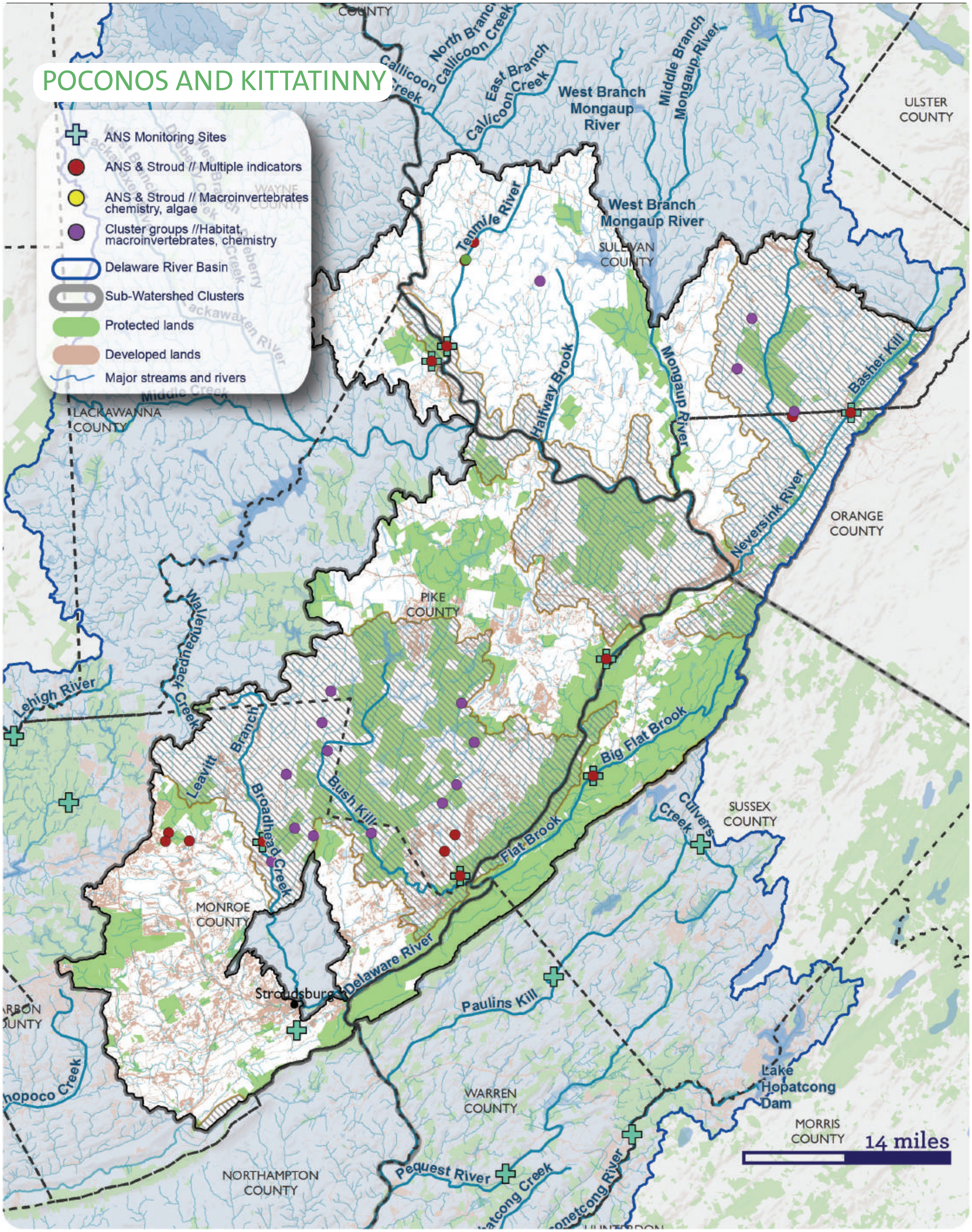
- Upper Delaware River Corridor
- The Neversink River
- Upper and Middle Brodhead Creek
- Bushkill/Hornbecks Creek

Cluster Group Monitoring

- The cluster group proposes water chemistry and macroinvertebrate downstream of land protection projects within the focus areas.
- Macroinvertebrate monitoring to be done by professional consultant and East Stroudsburg University. Funding is also being provided to water quality monitoring programs in Monroe (PA), Pike (PA) and Orange (NY) Counties. Monitoring is being coordinated with North Poconos CARE as well as Sullivan County (NY).
- Collaboration with East Stroudsburg University and Trout Unlimited by incorporating a stream monitoring program into undergraduate curriculum and/or developing a cluster-wide volunteer monitoring network.
- Cluster monitoring plan and budget include sampling over the 6 years beyond the grant period by certain partners.

ANS Monitoring and Quality Assurance

- Salamanders and algae will be collected by ANS at project sites (downstream of projects as well as additional control samples).
- All indicator sets will be monitored by ANS and SWRC at project sites not covered by cluster groups.
- Fish will be sampled from project sites not covered by NYS DEC, PA DEP or other local agencies. Currently, meetings are being scheduled with PA DEP and NY DEC.
- ANS shared chemical compound detection limits necessary and checked that cluster partner can meet detection levels. A number of samples are being analyzed by both ANS and partners during initial sampling events to test compatibility and equipment accuracy.
- Decisions will be made on which project sites will be monitored by cluster groups or ANS.
- Control sites will be defined for a set number of projects; several projects may share one control site.
- Control site selection will depend on potential for development upstream of project site as well as upstream of potential control sites.
- Fish (ANS) and macroinvertebrates (SWRC) will be taken for control samples. These sites are expected to be sampled in 2014 or 2015, depending on timing of land acquisition by cluster groups and project site monitoring.


POCONOS AND KITTATINNY
ANS Monitoring Sites
ANS & Stroud // Multiple indicators
ANS & Stroud // Macroinvertebrates chemistry, algae
Cluster groups //Habitat, macroinvertebrates, chemistry
Delaware River Basin
Sub-Watershed Clusters
Protected lands
Developed lands
Major streams and rivers
North Branch Callicoon Creek
Callicoon Creek
East Branch Callicoon Creek
West Branch Mongaup River
Middle Branch Mongaup River
ULSTER COUNTY
SULLIVAN COUNTY
Tenmile River
Halfway Brook
Mongaup River
Basher Kill
Neversink River
ORANGE COUNTY
LACKAWANNA COUNTY
Middle Creek
PIKE COUNTY
Wallenpaupack Creek
Lehigh River
Leavitt Branch
Broadhead Creek
Bush Kill
Big Flat Brook
Flat Brook
Culvers Creek
SUSSEX COUNTY
MONROE COUNTY
Stroudsburg
Delaware River
Paulins Kill
WARREN COUNTY
Lake Hopatcong Dam
MORRIS COUNTY
14 miles
NORTHAMPTON COUNTY
Pequest River
Pohopoco Creek

CLUSTER-SPECIFIC MONITORING PLANS

SCHUYLKILL HIGHLANDS

Cluster Group Monitoring

In this cluster, the priority land parcels are still being identified using monitoring data and models (Green Valleys Association; GVA) as well as parcel information (Natural Lands Trust; NLT). The cluster groups have a flexible approach to be implemented by GVA, SWRC and volunteer groups, especially the Hay Creek Watershed Association and Schuylkill Water Stewards.

Key Points

- The cluster team has agreed to use protocols used by ANS and SWRC, and to meet detection levels for water chemistry samples at ANS to be sure that monitoring partners' labs reach the same levels.
- Monthly chemistry samples in headwaters associated with septic field leaking.
- GIS modeling to integrate weather, land use, and stream sampling data to identify variables that account for year-to-year variation in trend analyses.
- Data for fine sediments, which had been neglected in past monitoring efforts, will be an important parameter in the new monitoring plan.

Key Indicators

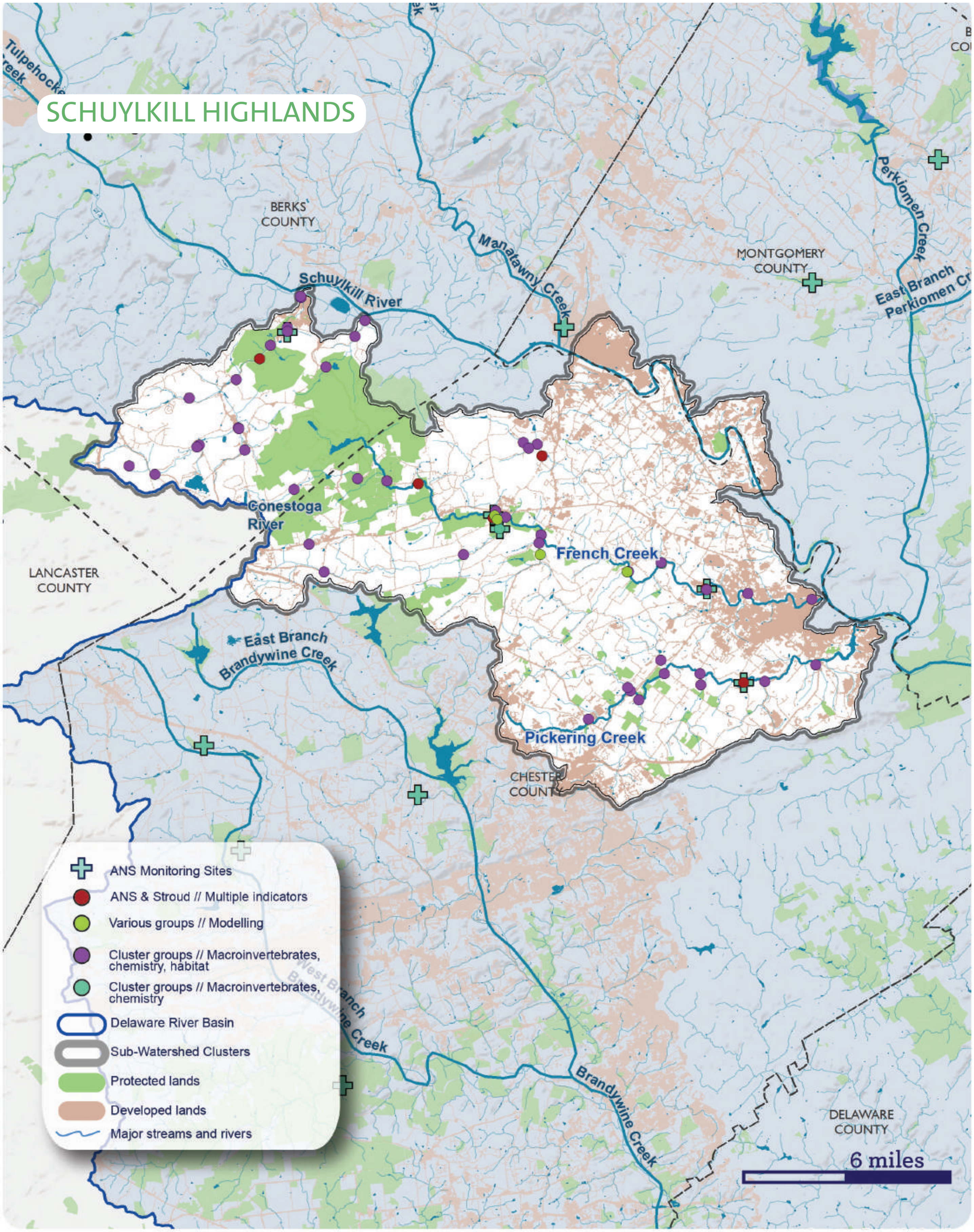
- Macroinvertebrates
- Total suspended solids, conductivity, total phosphorus, nitrate, chloride, dissolved oxygen and pH
- Habitat assessment
- E.coli

ANS Monitoring and Quality Assurance

ANS is working closely with SWRC and GVA to revise the Schuylkill Highlands monitoring plan such that samples are collected with a frequency that is reasonable for detecting ecosystem conditions without sampling too frequently to be relevant to project actions.

Cluster Group Modeling

This cluster also has clearly defined goals for using modeling as a planning tool and to contribute to the analysis of monitoring data. They are currently using modeling to identify streams and catchments which are least impacted by stormwater, sediments and nutrients – streams which are high priority for land conservation. The tool they are using, SWAT6, models sources, transport and fate of sediments, nutrients and bacteria, which have been found to be key stressors in most of French Creek. This information will be used to study the transport of fine sediment and to simulate upstream sources of stressors, providing information to support conservation scenario investigations and predict future outcomes and tailor monitoring approaches. Control sites will be defined for a set number of projects; several projects may share one control site. Control site selection will depend on potential for development upstream of project site as well as upstream of potential control sites.


SCHUYLKILL HIGHLANDS
BERKS COUNTY
MONTGOMERY COUNTY
LANCASTER COUNTY
CHESTER COUNTY
DELAWARE COUNTY
Tulpehocken Creek
Schuylkill River
Manatawny Creek
Perkiomen Creek
East Branch Perkiomen Cr
Conestoga River
French Creek
East Branch Brandywine Creek
Pickering Creek
West Branch Brandywine Creek
Brandywine Creek
ANS Monitoring Sites
ANS & Stroud // Multiple indicators
Various groups // Modelling
Cluster groups // Macroinvertebrates, chemistry, habitat
Cluster groups // Macroinvertebrates, chemistry
Delaware River Basin
Sub-Watershed Clusters
Protected lands
Developed lands
Major streams and rivers
6 miles

CLUSTER-SPECIFIC MONITORING PLANS

NEW JERSEY HIGHLANDS

Focus/Monitoring Areas

- Lower Musconetcong
- Upper Musconetcong
- Lopatcong Creek
- Upper Paulins Kill

Cluster Group Monitoring

The Nature Conservancy (TNC) and the Musconetcong Watershed Association plans to monitor approximately 30 total sites throughout the four focus areas, monitoring upstream and downstream of agricultural BMPs:

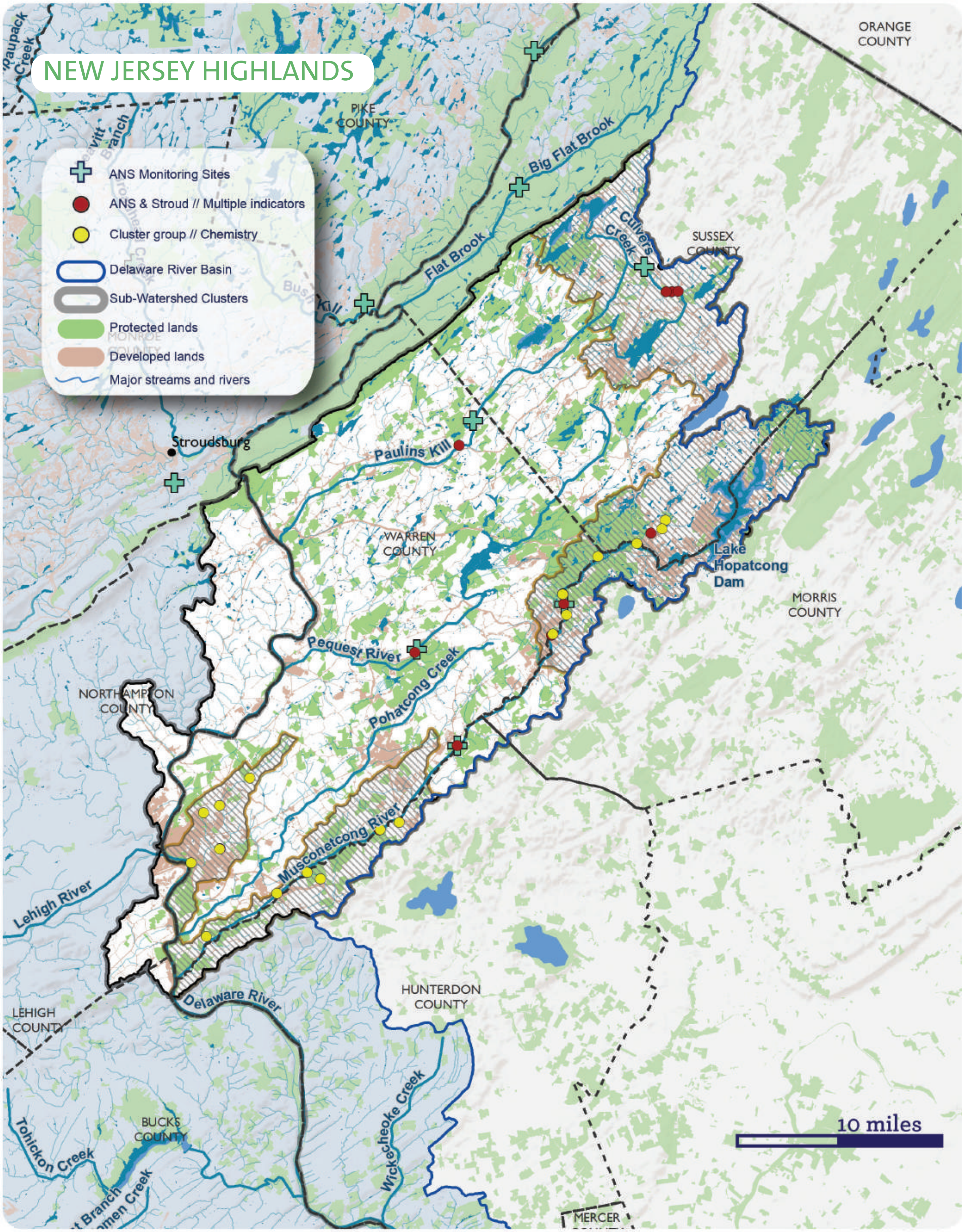
- Physicochemical indicators: twice a year for three years (DO, pH, temperature, turbidity)
- Macroinvertebrates: once a year for three years (2014 sampling performed by SWRC)
- Fecal coliforms: once a year for three years

Monitoring will be done by mixture of professional and volunteer resources. Land acquisitions and habitat connectivity will be monitored by a combination of land use/land cover monitoring and build-out/alternative scenario modeling (TNC).

ANS Monitoring and Quality Assurance

The initial locations of sites sampled by the cluster groups are similar to those in the Upper Lehigh cluster; they are located on the mainstems of major tributaries. Therefore, sites on smaller tributaries and close to project sites will be added by ANS and cluster groups.

- Where land acquisition and agricultural BMPs are implemented, ANS will add sites close to projects if they are not covered by the cluster monitoring.
- NJ DEP monitors fish in many sites in the focus areas annually, and once projects are defined this overlap will be assessed.
- This region is scheduled for macroinvertebrate monitoring by NJ DEP in 2017.
  - Therefore, restoration sites will be compared to the locations of NJ's Ambient Biomonitoring Network (AMNET) macroinvertebrate sites to align efforts with NJ DEP as discussed in a meeting between ANS & NJ DEP.
- ANS will sample salamanders and algae at project sites.
- ANS and SWRC will monitor all indicators at control sites.


NEW JERSEY HIGHLANDS
ANS Monitoring Sites
ANS & Stroud // Multiple indicators
Cluster group // Chemistry
Delaware River Basin
Sub-Watershed Clusters
Protected lands
Developed lands
Major streams and rivers
ORANGE COUNTY
PIKE COUNTY
SUSSEX COUNTY
WARREN COUNTY
MORRIS COUNTY
NORTHAMPTON COUNTY
HUNTERDON COUNTY
LEHIGH COUNTY
BUCKS COUNTY
MERCER
Big Flat Brook
Flat Brook
Culvers Creek
Bush Kill
Stroudsburg
Paulins Kill
Pequest River
Pohatcong Creek
Musconetcong River
Lake Hopatcong Dam
Lehigh River
Delaware River
Wickecheoke Creek
Tohickon Creek
10 miles

CLUSTER-SPECIFIC MONITORING PLANS

BRANDYWINE AND CHRISTINA

Focus/Monitoring Areas

- Honey Brook Headwaters
- Sharitz Run
- East Branch of White Clay Creek.
- Upper East Branch of Red Clay Creek
- Plum Run
- Upper East Branch Marsh Creek

Cluster Group Monitoring

- Honey Brook Headwaters
    - Leaf pack experiments and trout egg hatching monitored by volunteers, coordinated by SWRC
- Sharitz Run
    - Professional monitoring
        - Continuous water temperature, conductivity, and depth (2 sites)
        - Base flow turbidity (TSS), bacteria, and chemistry (alkalinity, nutrients (N and P) and ions) to match Academy of Natural Science of Drexel University protocol at integrative sites
        - Macroinvertebrates to match SWRC protocol (2 locations, middle and downstream PADEP site)
        - Stream sediment grain size (fines) and deposition rate (fines)
        - Fish, will be sampled initially to document fish community and then 5 years later when trees begin to shade the stream and summer high temperature increase (including assessment of trout survival, growth, and reproduction)
    - Student-Volunteer monitoring
        - Trout egg hatching (vibert boxes; 1X /yr)
        - Seedling survivorship and growth (all species; 1X/yr)
        - Leaf Pack Experiments (to link volunteer & professional data; 1X / 3yr)
- East Branch of White Clay Creek.
    - Professional monitoring
        - Temperature, conductivity and depth (4 sites)
        - Base flow TSS, bacteria and chemistry (alkalinity, nutrients [N and P] and ions) to match ANS protocols
        - Sediment grain size (fines) and deposition rate
        - Fish (initially, then 5 years later when trees begin to shade and summer high temperatures increase) including assessment of trout survival, growth and reproduction
    - Student-Volunteer monitoring
        - Trout egg hatching
        - Seeding survivorship and growth
        - Leaf pack experiments
- Strengthen municipal resource/riparian ordinances (Chester County)
    - Monitoring: water quality sampling coordinated with Stroud and ANS.

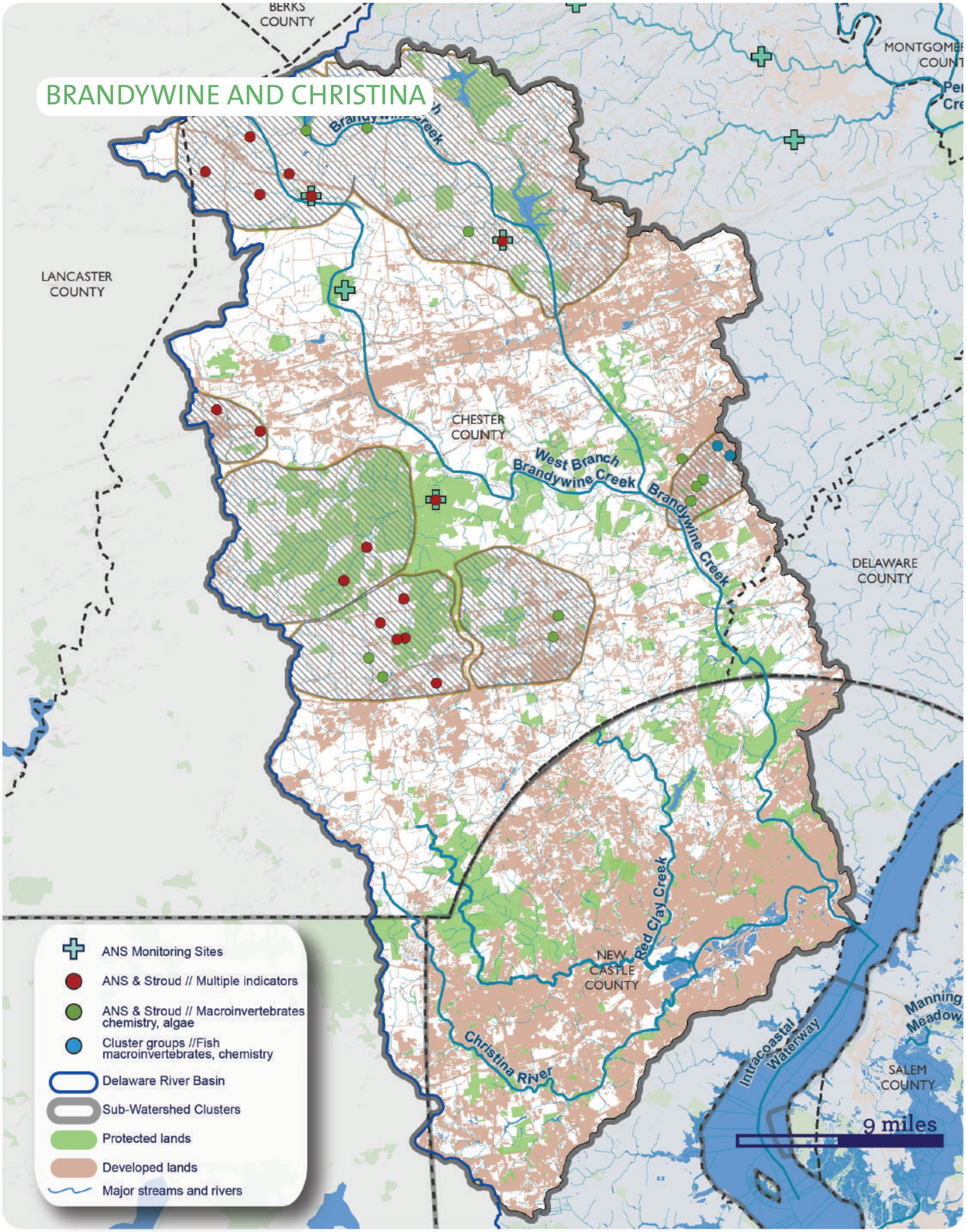
CLUSTER-SPECIFIC MONITORING PLANS

BRANDYWINE AND CHRISTINA

- Upper East Branch of Red Clay Creek
  - ICE protocol performed at sample points above and below project site in 2010
  - Will repeat ICE (chemistry, macroinvertebrates, habitat) in addition to standard SWRC/ANS method when projects are complete and improvement noted
  - Volunteer monitoring group at Kennett Golf Club
- Plum Run
  - Physiochemical and biological sampling was conducted at 14 sites in 2007
  - ICE (chemistry, macroinvertebrates, habitat) will be utilized after restoration based on volunteer monitoring results
  - Volunteer monitors have been sampling Plum Run and will conduct monitoring after project completion
- Little Buck Run
  - ICE performed in 2008. Will be repeated annually in spring before and after restoration.
  - Volunteer monitors have been sampling Buck Run and will conduct monitoring on Little Buck Run after project completion
- Upper East Branch Marsh Creek
  - Past monitoring by TNC and academic institutions will serve as baseline measurements of key indicators, developed in consultation with TNC and Stroud
  - SWRC will deploy continuously recording sensors (temperature, conductivity and depth) at 2 locations – above and below Great Marsh
  - Measurement of TSS, bacteria and chemistry in March/April/May to match ANS protocol at integrative sites
  - Macroinvertebrate sampling once per year to match ANS protocol;
  - Sediment grain size and deposition rate (fines)
  - Macroinvertebrate species inventory will be conducted at various locations in Great Marsh to correspond to plant inventory

ANS Monitoring and Quality Assurance

ANS will conduct chemical analysis of all water samples collected in the Brandywine-Christina cluster. SWRC plans to collect macroinvertebrates and fish from project sites, and ANS will sample salamanders and algae. SWRC and ANS will sample control and integrative sites throughout the grant period. Where the cluster group monitoring plan lacks upstream control sites, they will be sampled by SWRC or ANS after further discussions with cluster groups.


BRANDYWINE AND CHRISTINA
BERKS COUNTY
MONTGOMERY COUNTY
LANCASTER COUNTY
CHESTER COUNTY
DELAWARE COUNTY
NEW CASTLE COUNTY
SALEM COUNTY
West Branch Brandywine Creek
Brandywine Creek
Red Clay Creek
Christina River
Intracoastal Waterway
Manning Meadow
9 miles
ANS Monitoring Sites
ANS & Stroud // Multiple indicators
ANS & Stroud // Macroinvertebrates chemistry, algae
Cluster groups //Fish macroinvertebrates, chemistry
Delaware River Basin
Sub-Watershed Clusters
Protected lands
Developed lands
Major streams and rivers

CLUSTER-SPECIFIC MONITORING PLANS

MIDDLE SCHUYLKILL

Focus/Monitoring Areas

- Maiden Creek Watershed:
- Tulpehocken Creek Watershed:
- Manatawny Creek

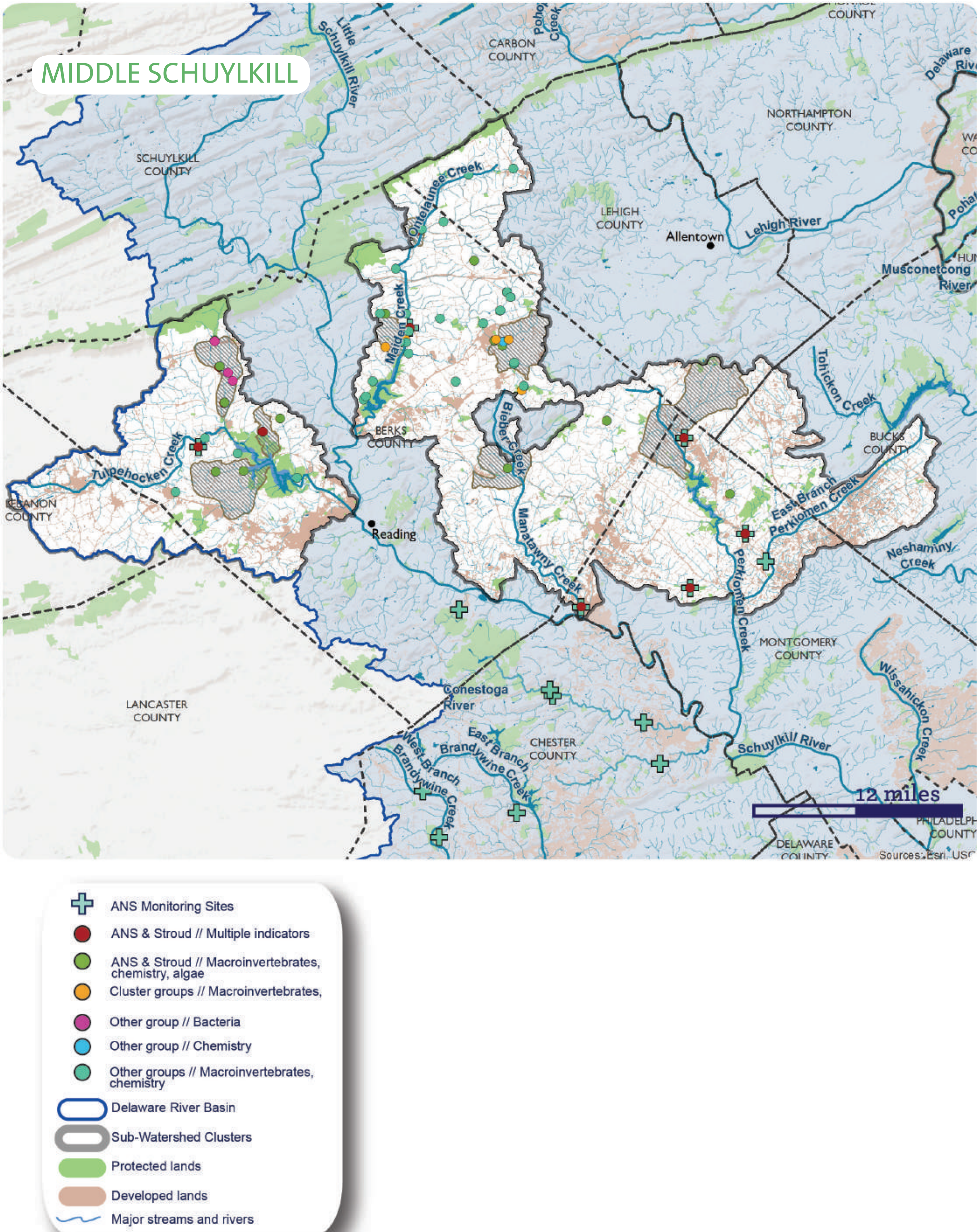
Cluster Group Monitoring

The cluster groups are currently planning to continue monitoring projects by collaborating with existing partners (Miller Environmental and macroinvertebrate consultant as well as existing Reading Water Authority and Schuylkill Action Network monitoring, within the same geographic area using additional funding sources) in source water protection monitoring as well as SWRC to coordinate volunteer groups. These two approaches would perform macroinvertebrate and water sampling for chemical analysis. This cluster's three-tiered approach to project readiness and monitoring has allowed them to work with ANS to plan for monitoring in 4-6 of the 8 focus areas in 2014. As projects are developed in the remaining areas, sampling sites will be defined by 2015.

- Maiden Creek Watershed
  - Saucony Creek (downstream of Martin farm)
  - Lower Maiden Creek (two unnamed tributaries upstream of Lake Ontelawnee)
  - Unnamed tributaries in Perry and Windsor Townships
- Tulpehocken Creek Watershed:
  - Licking Creek
  - Spring Creek
  - Northkill Creek
- Manatawny Creek

ANS Monitoring and Quality Assurance

ANS and SWRC will fill in gaps of indicator groups (especially fish, salamanders and algae in project sites), and monitor all indicators in control sites. These two research centers will also provide technical assistance and quality control for cluster monitoring groups. The cluster team has agreed to use chemistry sampling protocols used by ANS and to match detection levels for water chemistry samples set by ANS to be sure that monitoring partners apply the same levels.


MIDDLE SCHUYLKILL
CARBON COUNTY
SCHUYLKILL COUNTY
NORTHAMPTON COUNTY
LEHIGH COUNTY
Allentown
Lehigh River
Musconetcong River
Delaware River
Little Schuylkill River
Ontelaunee Creek
Maiden Creek
Tulpehocken Creek
LEBANON COUNTY
BERKS COUNTY
Reading
Bieber Creek
Manatawny Creek
Tohickon Creek
BUCKS COUNTY
East Branch Perkiomen Creek
Perkiomen Creek
Neshaminy Creek
MONTGOMERY COUNTY
Wissahickon Creek
LANCASTER COUNTY
Conestoga River
CHESTER COUNTY
East Branch Brandywine Creek
West Branch Brandywine Creek
Schuylkill River
DELAWARE COUNTY
12 miles
ANS Monitoring Sites
ANS & Stroud // Multiple indicators
ANS & Stroud // Macroinvertebrates, chemistry, algae
Cluster groups // Macroinvertebrates,
Other group // Bacteria
Other group // Chemistry
Other groups // Macroinvertebrates, chemistry
Delaware River Basin
Sub-Watershed Clusters
Protected lands
Developed lands
Major streams and rivers

CLUSTER-SPECIFIC MONITORING PLANS

UPSTREAM SUBURBAN PHILADELPHIA

The monitoring plan for the Philadelphia cluster includes monitoring at stormwater control measures (SCMs) as well as in streams receiving output from the SCMs. The cluster monitoring groups use the word "microwatersheds" to describe the drainage areas associated with SCMs. Temple-Villanova Sustainable Stormwater Initiative (T-VSSI) will initiate monitoring, field surveys and modeling. The Wissahickon Valley Watershed Association is coordinating citizen monitoring efforts throughout the cluster.

Priority Watersheds

- Pennypack Creek
- Poquessing Creek
- Tookany- Tacony Creek
- Wissahickon Creek
- Cobbs Creek

Cluster Group Modeling

T-VSSI will perform mathematical modeling for planning and evaluation of stormwater control methods (SCMs) at site-specific and microwatershed scales. Modeling goals are to determine efficacy of various models in predicting effect of SCMs implemented during Phase I (5 microwatersheds) and to compare alternative locations and combinations of SCMs to aid in the planning and sequencing of future stormwater facilities for Phase II (7 microwatersheds).

The HEC-HMS models for Pennypack, Wissahickon and Cobbs watersheds, and SWMM models for Poquessing and Tookany watersheds have been developed and calibrated as part of Act 167 Stormwater Management Plans. They will be modified and refined for each of the priority watersheds.

Cluster Group Monitoring

Monitoring goals:

- Evaluate effectiveness of SCMs
- Determine where new SCMs should be installed
- Develop smart phone applications to assist in volunteer monitoring and training
- Continue watershed group monitoring efforts
- Build watershed group monitoring in streams without a strong history of monitoring.

T-VSSI will monitor new SCMs and compare to existing T-VSSU sites following a four-tiered monitoring approach (Levels and variables are defined in Welker, Mandarano et al. 2013).

Monitoring of Individual SCMs:

- High level monitoring on approximately one SCM in each Phase I microwatershed. Includes inflows/outflows, rainfall, infiltration rate and water quality (total dissolved and suspended solids, temp, nutrients and metals, plant inventories where applicable). High level monitoring will also continue at several existing T-VSSI sites for comparison.

CLUSTER-SPECIFIC MONITORING PLANS

UPSTREAM SUBURBAN PHILADELPHIA

Monitoring of Individual SCMs continued...:

- Medium-level monitoring one to four SCMs per watershed. Includes inflows/outflows, rain and infiltration rate, plant inventories. Watershed groups will perform data collection with assistance from T-VSSI, who will analyze data.
- Low-level monitoring on all SCMs in watershed by combination of T-VSSI, watershed groups and trained citizens.
- Very Low-level monitoring performed by anyone using an App. Data will be analyzed by T-VSSI and reliability of data from the various sources will be considered.

Microwatershed Monitoring

- Turbidity monitoring can be initiated (or continued) on main stem reaches where existing stage monitoring is located
- Identify additional monitoring points to provide information on placement of SCMs.
- Use multiple levels of monitoring as above.
    - High level: the five Phase I microwatersheds
    - Medium and low level: fills in data gaps, evaluates initial stream response to SCMs and initiate monitoring in Phase II microwatersheds
    - App and website development to crowd source monitoring. Public can enter very low-level tier monitoring, trained volunteers can enter low level, municipal officials or engineers can enter low and medium level.

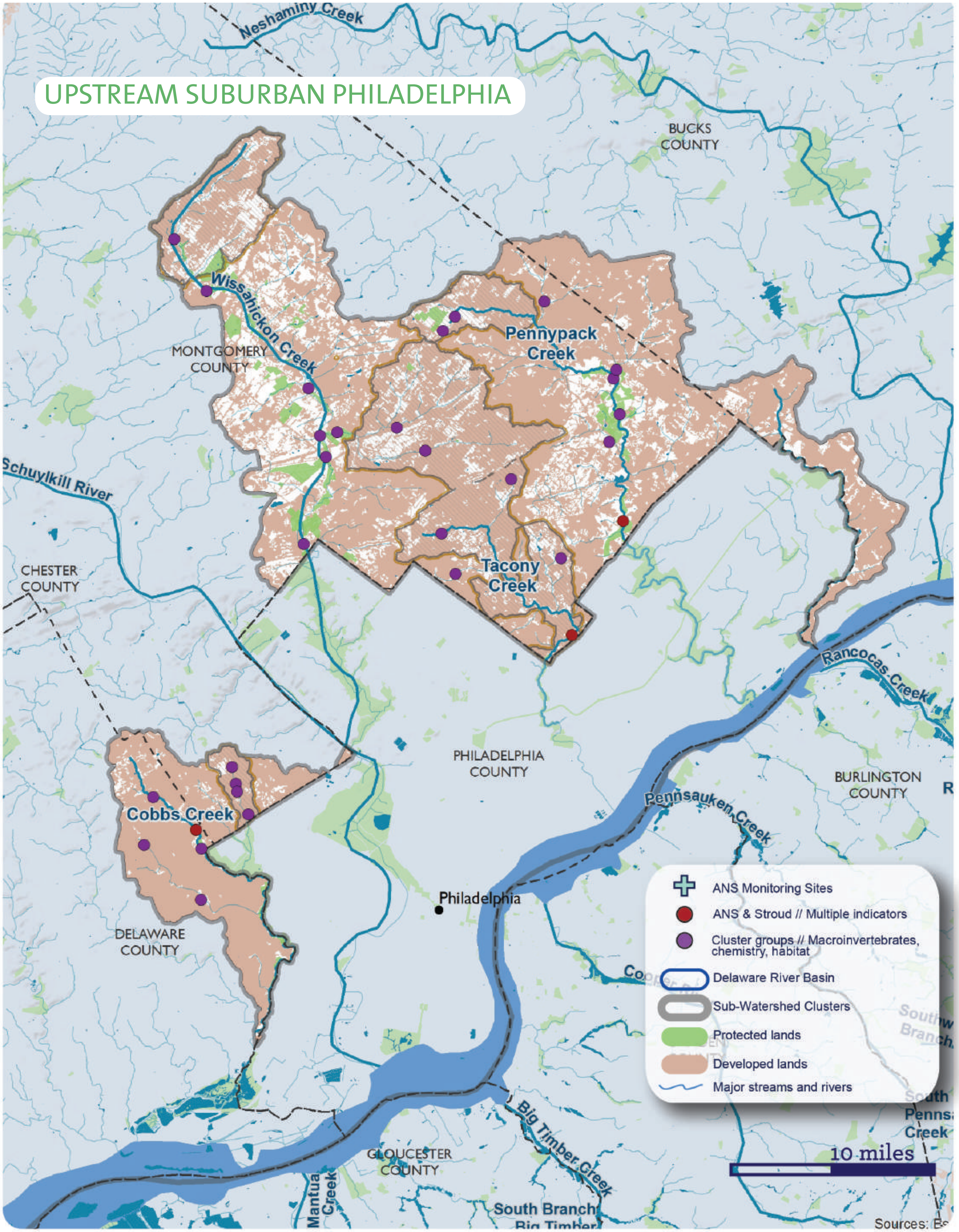
Temple University will use student researchers for monitoring some sites, and volunteer group monitoring is being organized for all streams by local watershed groups.

Stream Biomonitoring by Watershed Groups (Figure 7):

- Each watershed within the cluster has local watershed groups that perform outreach as well as project implementation. The groups that are participating in monitoring are:
    - Lower Merion Conservancy: 8 sites
    - Wissahickon Valley Watershed Association: 11 sites
    - Tookany-Tacony-Frankford Partnership: 5 sites
    - Pennypack Ecological Restoration Trust: 7 sites
    - Friends of Poquessing: 10 sites (starting in 2015)

ANS Monitoring and Quality Assurance

ANS will coordinate with watershed groups to cover sites and indicator groups in streams near SCMs. In addition, ANS and SWRC will monitor control sites: streams with similar characteristics but lower percentages of developed land and, if possible, similar areas with and without existing SCMs.


UPSTREAM SUBURBAN PHILADELPHIA
Neshaminy Creek
BUCKS COUNTY
MONTGOMERY COUNTY
Wissahickon Creek
Pennypack Creek
Schuylkill River
Tacony Creek
CHESTER COUNTY
Rancocas Creek
PHILADELPHIA COUNTY
BURLINGTON COUNTY
Pennsauken Creek
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Sub-Watershed Clusters
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Major streams and rivers
Big Timber Creek
GLOUCESTER COUNTY
Mantua Creek
South Branch Big Timber
10 miles

CLUSTER-SPECIFIC MONITORING PLANS

KIRKWOOD COHANSEY AQUIFER

Focus/Monitoring Areas

- Southwest Branch Rancocas Creek
- Core Pine Barrens
- Greater Hammonton
- Salem River
- Cohansey-Maurice Rivers
- Western Cape May County

Cluster Group Monitoring

In most cases, impacts on water table level, water chemistry and biological communities will be difficult or impossible to measure because projects relate to a large area and the effects of a given action may either take years to develop and/or would be impossible to isolate the effects from "noisy" natural system. Cluster partners are using different analyses to assess the hydrologic condition of the aquifer:

- In-stream flow, which can be measured and modeled in a variety of ways using a variety of possible thresholds. This is the focus of NJDEP and the work Bob Kecskes proposes to do for American Littoral Society and ANJEC proposes in the Bayshore portion of the cluster.
- Wetlands impacts, in terms of reduced water table level in wetlands due to withdrawals. This is a model USGS created as part of the Kirkwood-Cohansey Study, based on the Gompertz equation. Bob Kecskes and his colleague Manny Charles have taught participants how to run the model, and we are doing that which is being done for the Hammonton and SW Branch of the Rancocas focus areas on a HUC-14 basis.
- Water table impacts measured on a well-by-well, cone of depression basis through a Theim equation (developed by USGS as part of the Kirkwood-Cohansey Study). The Pinelands Commission prefers this local, case-by-case modeling over the HUC-14-wide wetlands impact analysis and will be using this model to measure water table impacts
- A simple percent of recharge withdrawn on some watershed scale. The Commission has been using this kind of analysis to evaluate proposed new or increased water allocations from the K-C aquifer. Cluster partners are working to determine the proper the scale for this analysis (HUC12 or HUC14).

CLUSTER-SPECIFIC MONITORING PLANS

KIRKWOOD COHANSEY AQUIFER

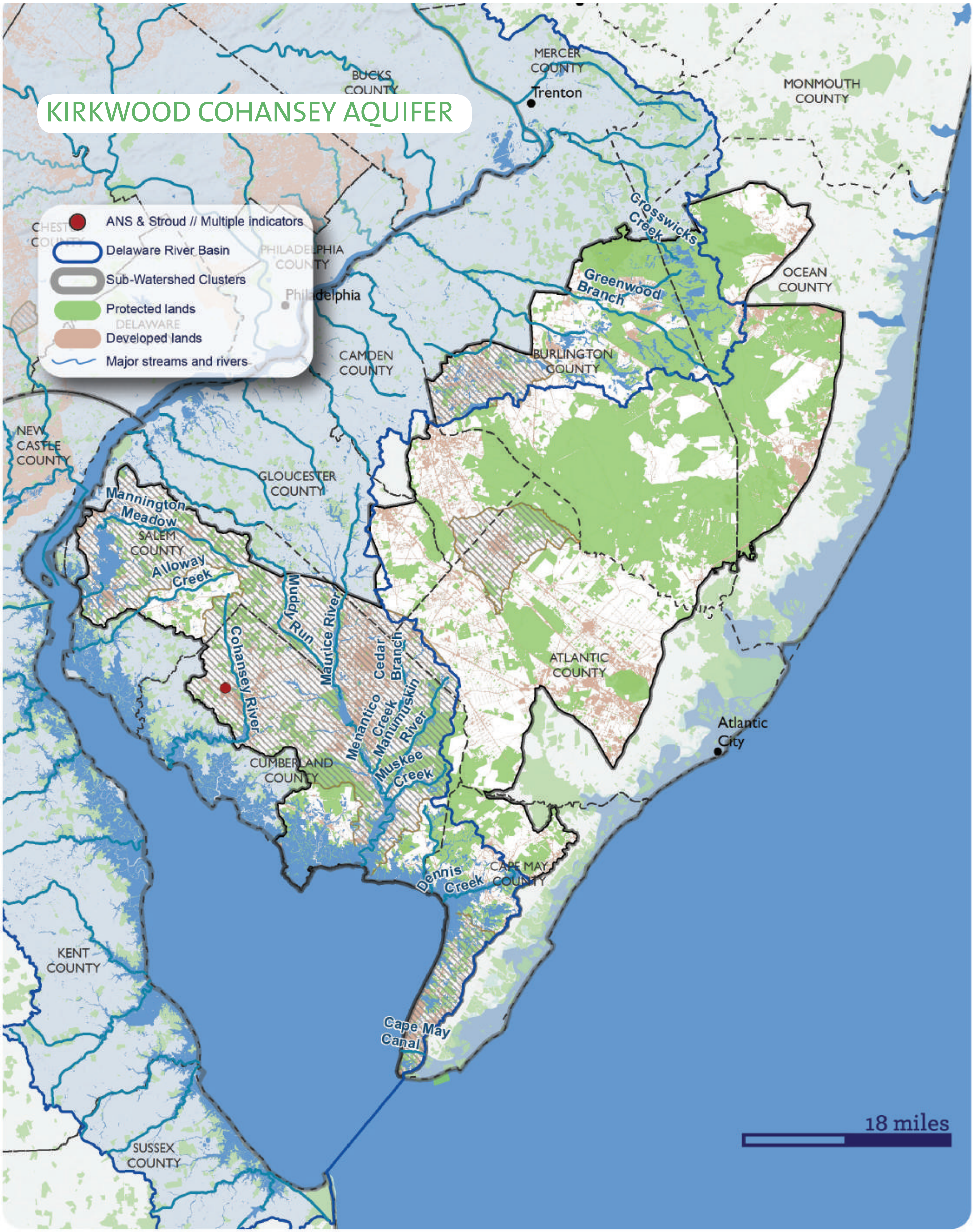
Cluster group modeling

In the fall of 2014, the Partnership for the Delaware Estuary convened non-profit partners and governmental agencies working in the area to build a monitoring and modeling plan for assessing the quantity and quality of groundwater related to this initiative. They will use the data described above that is being collected by the USGS and NJ DEP to apply models developed by researchers from those agencies. Using extensive, long-running monitoring programs by various public agencies and scientific studies by academic and government scientists, the cluster will be able to identify usable thresholds (such as percent land use and alteration of basin) and relationship (such as upland farming and nitrogen inputs) to model the impacts of the planned activities on key indicators.

ANS project monitoring

In 2014 ANS is piloting an edge-of-field sediment trap on Barrett's Run and performing lentic macroinvertebrate sampling, which is better suited to this ecosystem type. ANS and project partners will monitor long-term impacts of fundamental indicators, mainly from existing data sources:

- Water chemistry from wells (existing data) and streams (existing data & ANS sampling): pH (for acid waters) and nitrogen (for all waters). Other contaminants are degrading the aquifer in some places, but the cluster partners believe focusing on pH and nitrogen will have the greatest impact on long-term health of entire aquifer. Macroinvertebrates have proven less reliable to measure water quality in K-C waters.
- Water volume measures: water table level, passing flows in streams and depletive withdrawals from K-C and hydrologically-connected aquifers.
- Native biodiversity of wetlands and riparian areas.
- Surface waters sites with potential for groundwater exchange and connections to BMPs. ANS is developing a long-term monitoring plan for this cluster and baseline characterization using groundwater data. ANS will be working with groundwater models with the USGS to examine streams near project areas where groundwater exchange is likely. Scientists at ANS are corresponding with NJ DEP and USGS to design monitoring plans for projects once the locations are known.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MERCER COUNTY
Trenton
MONMOUTH COUNTY
PHILADELPHIA COUNTY
Philadelphia
OCEAN COUNTY
Crosswicks Creek
Greenwood Branch
CAMDEN COUNTY
BURLINGTON COUNTY
NEW CASTLE COUNTY
GLOUCESTER COUNTY
Mannington Meadow
SALEM COUNTY
Alloway Creek
Muddy Run
Maurice River
Cohansey River
Cedar Branch
Menantico Creek
Manumuskin River
Muskee Creek
ATLANTIC COUNTY
Atlantic City
CUMBERLAND COUNTY
Dennis Creek
CAPE MAY COUNTY
KENT COUNTY
Cape May Canal
SUSSEX COUNTY
18 miles

MONITORING PLAN DEVELOPMENT, 2013-2014

The exact locations of many project sites have been released with project funding announcements in 2014. In 2014, sampling took place where projects will be implemented; projects that do not receive funding can be omitted from future samples or used as controls where appropriate. Monitoring in 2014 will ensure that data are available on ecological conditions before the implementation of projects. In 2015, new projects will be funded, and these areas will also be monitored before implementation. In subsequent years, projects will continue to be monitored before and after on-the-ground actions are carried out.

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FOUNDED IN 1812, the Academy of Natural Sciences of Drexel University is a leading natural history museum dedicated to advancing research, education, and public engagement in biodiversity and environmental science.

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