# Appendix I: Water Quality Sampling Site Selection and Maps

## Introduction & Background

### Introduction

This appendix describes the vital signs analysis and approach to water quality monitoring during Phase 3 of the SCPN's protocol development process. Water quality, one of the high-priority vital signs emphasized at the network level, is an important ecosystem characteristic that, in part, describes the condition of critical functions of streams, seeps and springs, and tinajas. SCPN recognizes water-quality is a critical component of dynamic riparian and aquatic ecosystem functions in many of the park units. These significant ecosystems include riparian corridors, stream channels, and hanging gardens.

The National Park Service Natural Resource Challenge (NRC) provides funding for water quality monitoring within National Park Service (NPS) units. The purpose is to track the attainment of the Service's long-term water quality strategic goal of significantly reducing pollution in park water bodies. The NPS is also committed to preserving existing pristine water quality in parks, including waters classified as Outstanding National Resource Waters (ONRW's) or state-equivalent listed waters. As part of this initiative, starting in FY2003, the SCPN received $124K per year from NPS Water Resources Division (NPS/WRD) to conduct water quality monitoring and assist in achieving the following NPS objectives:

- Protection of designated uses, which involve 303(d)-listed waters, Outstanding Natural Resource Waters, or other designated waterbodies under provisions of the Clean Water Act.
- Documentation of water quality parameters that are vulnerable to alteration from various sources of contamination or land use practices.
- Establishment of water quality parameters useful for indicating ecosystem integrity of particular water resources.
- Establishment of baseline conditions.

Specific SCPN aquatic resource monitoring objectives support management in relation to 303(d) listing of waters, designation of Outstanding National Resource Waters, and protection of designated uses. SCPN monitoring objectives also provide data for associated aquatic resource vital signs. SCPN aquatic resource objectives are:

- Determine status and trends in the water quality of selected streams and springs. Priorities for monitoring include impaired stream reaches and relatively pristine waters.
- Determine status and trends in the composition and abundance of aquatic macroinvertebrate assemblages, and in the distribution and condition of aquatic macroinvertebrate habitats, in selected perennial streams.
- Determine status and trends in spring discharge, habitat area, vegetation composition and structure, aquatic and riparian invertebrate composition and abundance, *Rana pipiens* occurrence, and *Hyla arenicolor* abundance.
- Determine status and trends in composition and structure of riparian vegetation along selected streams or stream reaches.
- Determine status and trends in physical drivers of riparian ecosystems (i.e., stream flow, depth to water in alluvial aquifers and channel morphology) in selected streams or stream reaches.

The emphasis of the NPS/WRD and the NRC is on water quality of streams and springs; however, the SCPN acknowledges the importance of water quantity in the arid southwest. In many of the fluvial ecosystems in this network, the impact of drought and flood events will far outweigh that of water quality. Likewise, changes in regional aquifer levels influence flows from springs and affect the ecological integrity of associated communities. Monitoring water quantity as well as quality is essential in order to address aquatic resource issues in the SCPN adequately. As recommended by the NPS/WRD, the network will integrate the design and implementation of water quality monitoring within the broader monitoring program. Consequently, water quality and water quantity issues will be considered simultaneously during the vital signs selection process.

## Background

The Southern Colorado Plateau Network includes 19 park units. A general description of water resources in the SCPN is provided in Appendix C of this report. None of the surface waters in SCPN have been classified by the states as Outstanding Natural Resource Waters.

Four streams in SCPN parks have been identified as impaired and included on 303(d) lists by the States of Arizona and New Mexico (Table I1). Causes for impairment include sedimentation, suspended sediments, turbidity, temperature, benthic macroinvertebrates, fecal coliforms, DDT, and selenium. Additionally, reaches of two streams upstream of SCPN parks in Colorado and Utah are on these states 303(d) lists. These are the Mancos River near Mesa Verde National Park and the Paria River near Glen Canyon National Recreation Area. Causes for impairment in these streams include copper, salinity, chlorides, and total dissolved solids.

Water-quality monitoring will include the five core water quality parameters required by the National Park Service Water Resources Division (NPS-WRD). These parameters are temperature, specific conductance, pH, dissolved oxygen, and streamflow. A detailed discussion of the rationale for selecting the five core parameters can be found in the document “Recommendations for core water quality monitoring parameters and other key elements of the NPS Vital Signs Program water quality monitoring component” (National Park Service 2002). The SCPN water quality monitoring protocol will also include field measurements of turbidity. In addition to the core parameters, water samples will be collected and analyzed for major ions, nutrients, and selected trace metals. At sites identified by the states in their 303(d) listings, monitored regulatory parameters will depend on both the current and historic causes for listing and the specific criteria that each state uses to define the use categories or classes of its surface waters.

Aquatic macroinvertebrates are included as a SCPN vital sign and will be monitored in conjunction with water quality at most proposed monitoring sites. Aquatic macroinvertebrates inhabit sediments or live on the bottom substrates of streams and springs. Aquatic macroinvertebrate assemblages in streams reflect overall biological integrity of the benthic community. Monitoring these assemblages is useful in assessing the status of the waterbody and detecting trends in ecological condition. Benthic communities respond to a wide array of stressors in different ways so that it is often possible to determine the type of stress that has affected a macroinvertebrate community (e.g. Klemm et al. 1990). Because many macroinvertebrates have relatively long life cycles (a year or more) and are relatively immobile, macroinvertebrate community structure is a function of present or past conditions.

**Table I1. Impaired waters included on Section 303(d) list that are inside SCPN park unit boundaries[1].**

| Name of Waterbody | Description | State | Park Unit | Exceedances |
|---|---|---|---|---|
| Animas River | From Estes Arroyo to the NM-CO border | NM | AZRU | Temperature |
| Capulin Creek | From the mouth on the Rio Grande to the headwaters | NM | BAND | Benthic/macroinvertebrate bioassessment and sedimentation |
| Rito de los Frijoles | Rio Grande to headwaters | NM | BAND | Fecal coliform, temperature, DDT, and turbidity |
| Colorado River | Parashant Canyon to Diamond Creek | AZ | GRCA | Selenium and suspended sediments |
| Paria River | Utah border to Colorado River | AZ | GLCA | Suspended sediments and possibly turbidity |
| **On Planning List Due to Lack of Sufficient Data** | | | | |
| Lake Powell | Entire Lake | AZ | GLCA | *E. coli* exceedance in last 3 years, inconclusive data for other core parameters |
| Colorado River | Lake Powell to Paria River | AZ | GLCA | Missing core parameters (total fluoride & total boron) |

[1]Information for this table from 2004 Integrated 505(b) Assessment and 503(d) Listing Report for Arizona and 2004-2006 State of New Mexico Integrated Clean Water Act 303(d)/305(b) Report Water Quality and Water Pollution Control in New Mexico

## Sampling Design

The SCPN approach to sampling design is described in Chapter 4 of this report. *Judgmental* (specific water bodies and locations are targeted based on what is known) design was used to select a preliminary group of water quality index sites (Table I2 and Figures I1a-I1h). A list-based design will be used to select spring monitoring sites at Glen Canyon National Recreation Area. Judgment is a major component of most water quality monitoring designs and most states primarily utilize judgmental (non-random) designs focused on answering specific management questions (U.S. Environmental Protection Agency 2002).

Water quality monitoring for the SCPN will be conducted at fixed monitoring sites. The sampling design follows the strategies described by the USGS National Water Quality Assessment (NAWQA) program for basic and intensive fixed site assessments (Shelton 1994). Basic fixed site assessments characterize the spatial and temporal distribution of general water quality and constituent transport in relation to hydrologic conditions and contaminant sources. Intensive fixed site assessments characterize seasonal and short-term temporal variability of general water quality and constituent transport and determine the occurrence and seasonal pattern transport of contaminants.

The location and site selection criteria for proposed water monitoring sites are based on project objectives and the spatial and temporal variability of the hydrologic system. Waterbodies included on State Clean Water Act Section 303(d) lists are high priorities for monitoring and have one or more of the following characteristics: have an established threat, lack adequate current baseline data, and are subject to ecological impairment or are linked to another vital sign indicator (e.g. stream T&E and fish assemblages). An undisturbed or near-pristine site, where present within a watershed, may be suitable as a “reference reach.” This stream would be most similar to other streams in the watershed in geology and be the most natural (unaltered geomorphology and land use).

Co-locating water quality monitoring sites with past, current, or proposed macroinvertebrate or integrated riparian monitoring sites will help ensure data linkages.

For regulatory monitoring, site selection depends in large part upon the specific stream reaches identified by the states, and the listed impairment. The SCPN target "population", or group of index streams and springs proposed for water quality monitoring, was chosen based on preliminary review of data from a provisional version of the SCPN water quality database (Brown and Wynn In progress), review of provisional data collected through the current Level 1 water-quality inventory of SCPN parks, review of the Horizon reports, and results of water quality planning meetings (and park staff prioritization).

Criteria used to eliminate potential target water bodies due to one or more of the following exceptions were:

- Other entities are implementing adequate water-quality monitoring programs. Water bodies in SCPN consistently monitored by other entities are the Colorado River in Grand Canyon National Park (suspended sediment), Lake Powell and the Paria River (suspended sediment) in Glen Canyon National Recreation Area, Rito de los Frijoles in Bandelier National Monument (DDT), and possibly the Animas River at Aztec Ruins National Monument (temperature). It is appropriate and fiscally responsible not to monitor these streams if the parks have access to the data and the data meet the needs of the monitoring program.

- The EPA's Consolidated Assessment and Listing Methodology (CALM) provide examples of stratification for rivers/streams, lakes, wetlands, and estuaries (U.S. Environmental Protection Agency 2002). Rivers/streams are stratified into intermittent, wadeable, and nonwadeable/deep river. The sampled population for SCPN, during protocol testing and refining, will include wadeable and intermittent streams. For the purposes of this monitoring plan, this includes streams that are safely wadeable except in heavy storm or flood conditions. Water bodies in SCPN that are not wadeable include the Animas River at Aztec Ruins National Monument, the Rio Grande at Bandelier National Monument, the Colorado River in Grand Canyon National Park, and the Colorado and San Juan Rivers in Glen Canyon National Recreation Area. Within SCPN, ephemeral drainages are numerous, and are most often small and unnamed. Most drainages of this type of are not considered for monitoring. Ephemeral washes at Petroglyph National Monument are included as proposed monitoring sites because erosion and sedimentation are highly significant management issues for that monument.

Examples of stratification in water quality include broad stream type (perennial, intermittent, ephemeral), watershed size, stream pattern (straight, meandering, braided) or other channel characteristics. Sampling can also be stratified by time (e.g. by varying the order of sampling sites). For SCPN, since streams are diverse, with dissimilar substrate and channel type, neither watershed size, hydrologic conditions, nor stream classification schemes will be used to decide on water quality monitoring locations. Where available, existing or past monitoring stations will be utilized. However, the existing or past sites will be evaluated to determine if monitoring will address specific network objectives.

**Table I2. Preliminary list of SCPN streams and springs selected for water quality monitoring.**

| Park | Site | Latitude | Longitude | Current Streamflow gage |
|---|---|---|---|---|
| AZRU | Animas River | 36.833 | -108.00 | None |
| BAND | Frijoles Creek at Hdqrs Gage | 35.776 | -106.27 | X |
| BAND | Capulin Creek below Base Camp | 35.756 | -106.33 | None |
| CACH | Chinle Wash near White House Ruin | 36.133 | -109.47 | None |
| CACH | Tsaile Creek at Bare Rock Trail | 36.152 | -109.47 | None |
| HUTR | Pueblo Colorado Wash | 35.710 | -109.56 | None |
| MEVE | Mancos River | 37.280 | -108.36 | X |
| PEFO | Puerco River | 34.979 | -109.79 | None |
| PETR | North Boca Negra Arroyo | 35.160 | -106.72 | None |
| GLCA | Escalante River abv Stevens Canyon | 37.436 | -110.98 | None |
| GLCA | Coyote Gulch above Escalante River | 37.428 | -110.99 | None |
| GLCA | Stevens Canyon at Mouth | 37.436 | -110.97 | None |
| GLCA | Paria River | 36.872 | -111.59 | X |
| GLCA | Lake Canyon at Hole in Rock Trail | 37.388 | -110.62 | None |
| GLCA | Wahweap Creek | 37.051 | -111.62 | None |
| GRCA | Cottonwood Creek | 36.024 | -111.99 | X |
| GRCA | Hermit Creek | 36.081 | -112.21 | X |
| GRCA | Havasu Creek | 36.306 | -112.76 | X |
| GRCA | Nankoweap Creek | 36.251 | -111.93 | None |
| GRCA | Robbers Roost Creek | 36.269 | -112.09 | None |
| BAND | Frijoles Spring | 35.751 | -106.26 | None |
| CHCU | Wijijii Spring | 36.016 | -107.87 | None |
| ELMO | Historic Pool at El Morro | 35.040 | -108.35 | None |
| GRCA | Cottonwood Spring | 36.017 | -111.99 | None |
| GRCA | Hawaii Spring | 36.033 | -112.22 | None |
| GRCA | Nankoweap Spring | 36.228 | -111.95 | None |
| GRCA | Roaring Springs | 36.033 | -112.18 | None |
| GRCA | Robbers Roost Spring | 36.281 | -112.09 | None |
| NAVA | Keet Seel Ruin Spring | 36.759 | -110.49 | None |
| PEFO | Kokopelli Spring | 34.957 | -109.79 | None |
| SAPU | Abó Spring | 34.450 | -106.38 | None |
| WACA | Cherry Spring | 35.154 | -111.48 | None |
| WUPA | Heiser Spring | 35.506 | -111.35 | None |
| YUHO | Aztec Spring | 37.250 | -108.69 | None |

## Specific Sampling Site Selection

Specific water quality monitoring sites in SCPN will be located based on the following guidelines (Wilde 2005):

- At or near a streamflow gaging station, to obtain concurrent surface water discharge data required for computing constituent transport loads and for determining discharge/constituent concentration relations. Measure discharge at time of sampling if a stream-gaging station is not at or near the sampling site or if discharge cannot be rated or estimated with sufficient accuracy.

- In straight reaches having uniform flow, and having a uniform and stable bottom contour, and where constituents are well mixed along the cross section.

- Far enough above and below confluences of streamflow or point sources of contamination to avoid sampling a cross section where flows are poorly mixed or not unidirectional.

- In reaches upstream from bridges or other structures, to avoid contamination from the structure or from a road surface.

- In unidirectional flow that does not include eddies. If eddies are present within the channel, sample only the unidirectional flow.

- At or near a transect in a reach where other data are collected (such as data for suspended sediment, bedload, bottom material, or biological material) and/or for which historical data are available.

- At a cross section where samples can be collected at any stage throughout the period of study, if possible.

## Measurable Objectives

The development of measurable objectives is a critical element of any monitoring protocol. Regulatory monitoring (i.e., monitoring conducted under the provisions of the CWA) asks the general question: Does parameter "X" exceed state standards? In most cases, the critical parameters or suites of parameters for monitoring (e.g. cause for listing) are identified by the reporting requirements of these CWA programs, and these parameters can be incorporated into the specific monitoring objective on a site-by-site basis.

The site-specific objectives for each waterbody monitored as part of the SCPN's regulatory water quality monitoring program are based on the states' 2004 303(d) lists. The SCPN will work cooperatively with state agencies to ensure that any monitoring of 303(d) listed waterbodies meets state credible data requirements and complements the efforts of state programs. Communication with state programs is required to keep abreast of any changes in state 303(d) lists, which are updated every two years. The SCPN will review state assessments annually to determine whether additional measurable objectives need to be developed for the regulatory water quality-monitoring program.

The general monitoring goals recommended by the NPS-WRD are to:

1. determine whether the overall goal of improved water quality is being achieved; and
2. gather information on the pollutants that exceed standards to assist the park and the state in designing specific pollution prevention or remediation programs through Total Maximum Daily Loads.

## Data Representativeness and Sampling Constraints

There are physical constraints to sampling as well as data representativeness constraints and, in some cases, these constraints are the same. Sampling schedules will be designed to capture representative site-specific hydro periods. Ideally all sites within a given watershed are sampled on the same day (or even around the same time) or during the same storm event. Sites should represent inputs from all areas of the watershed (i.e., all major tributaries). When choosing the number of sites within a watershed, we want to be as comprehensive as possible in representing the watershed while choosing a number of sites that is practical (considering laboratory and staff costs and logistics). To help ensure that the data collected (sampled population) adequately represent the target population, automated samplers may be deployed in some cases to help gain an understanding of seasonal and diel variability. Some constraints to sampling representatively include difficult or unsafe access, particularly during storm events.

Water quality varies over space and time. Rivers and streams tend to be well mixed; thus, depth integration is not a significant issue except in the dry seasons when flow may be very slow or only pools may be present. The USGS National Field Manual (U.S. Geological Survey variously dated) refers to sampling as either non-isokinetic or isokinetic sampling (depth-integrated). The study objectives need to be considered when determining sample collection procedures.

## Sampling Frequency

Monitoring at fixed stations requires regular visits by sampling technicians to manually collect field parameters and any other site-specific samples selected by the network for lab analysis. Establishing conclusive trends from sampling data collected synoptically or intermittently can be very difficult. Depending on funding and staff constraints, a "rotating basin" scenario may be implemented in order to monitor the maximum number of waterbodies of concern. This would enable monitoring of more water bodies on a fixed budget. USGS NAWQA (National Water Quality Assessment) protocols recommend a minimum of two years per monthly sampling period (Gilliom et al. 2001) for rotating basin designs. A phasing-in approach (gradually adding more watersheds over time) will also be considered depending upon funding. This would allow longer-term data sets for trends, without two-year gaps. It also allows time to explore additional funding opportunities, partnerships, and ways of streamlining the monitoring program and enabling it to be more comprehensive.

## Field and Laboratory Methods

All aspects related to field and laboratory methods will be included in Standard Operating Procedures (SOPs). Methods used will follow existing national programs (EPA and USGS). When exceptions are made, they will be documented in the SOPs. Quality assurance and quality control methods follow EPA-approved guidelines for Quality Assurance Project Plans. SOPs will cover field season preparations and equipment, sequence of events in the field, details of taking measurements (including example field forms), post-collection processing of samples (e.g. lab analysis), end-of-season procedures, QA/QC, and all other details of water quality monitoring.

## References

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Gilliom, R., W. M. Alley, and M. E. Gurtz. 2001. Design of the National Water-Quality Assessment Program. United States Geological Survey.

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U.S. Geological Survey. variously dated. National field manual for the collection of water-quality data. *in* U.S. Geological Survey Techniques of Water-Resources Investigations Book 9. online at http://pubs.water.usgs.gov/twri9A.

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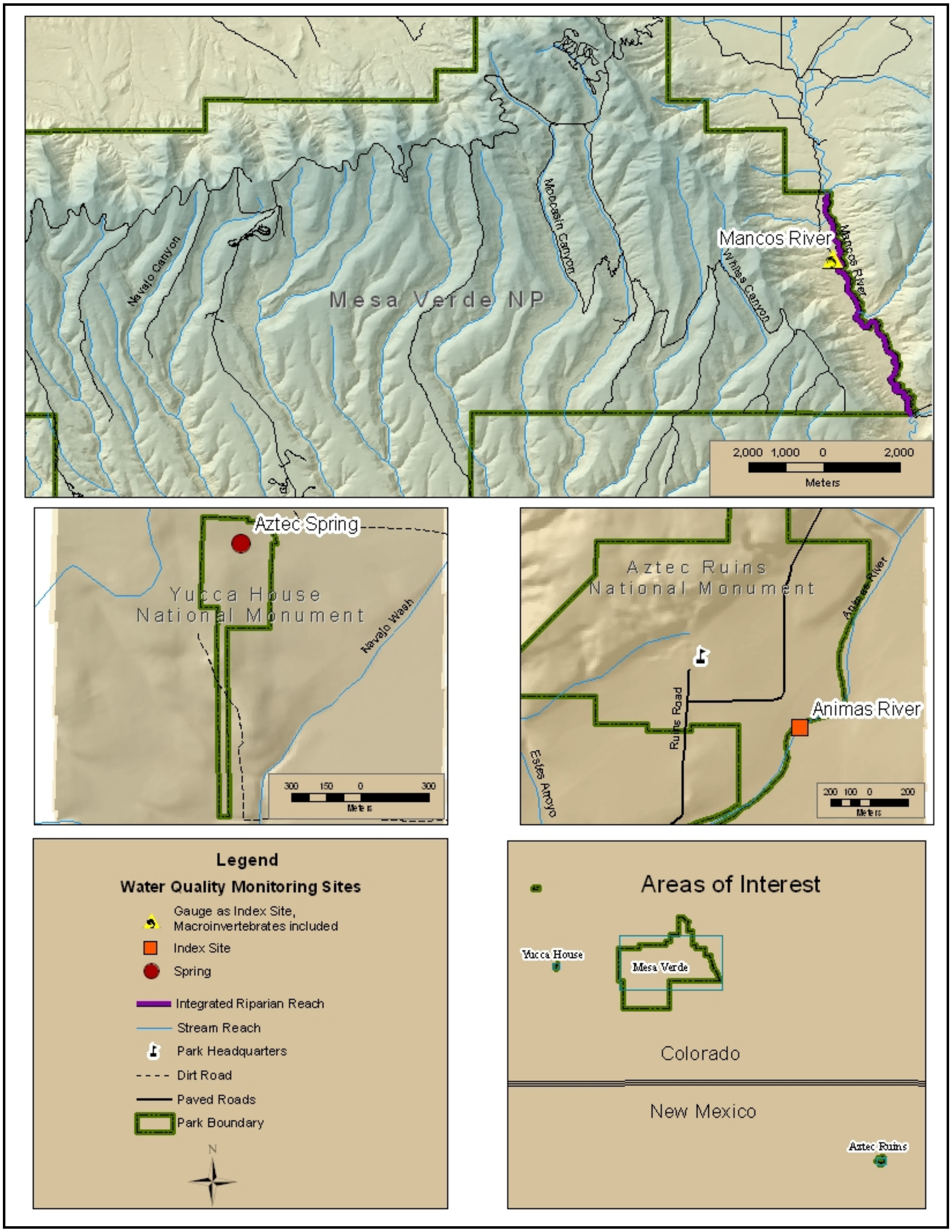


**Figure I1a. Proposed SCPN stream water quality, aquatic macroinvertebrate, integrated riparian, and spring monitoring sites at Aztec Ruins National Monument, Mesa Verde National Park, and Yucca House National Monument.**

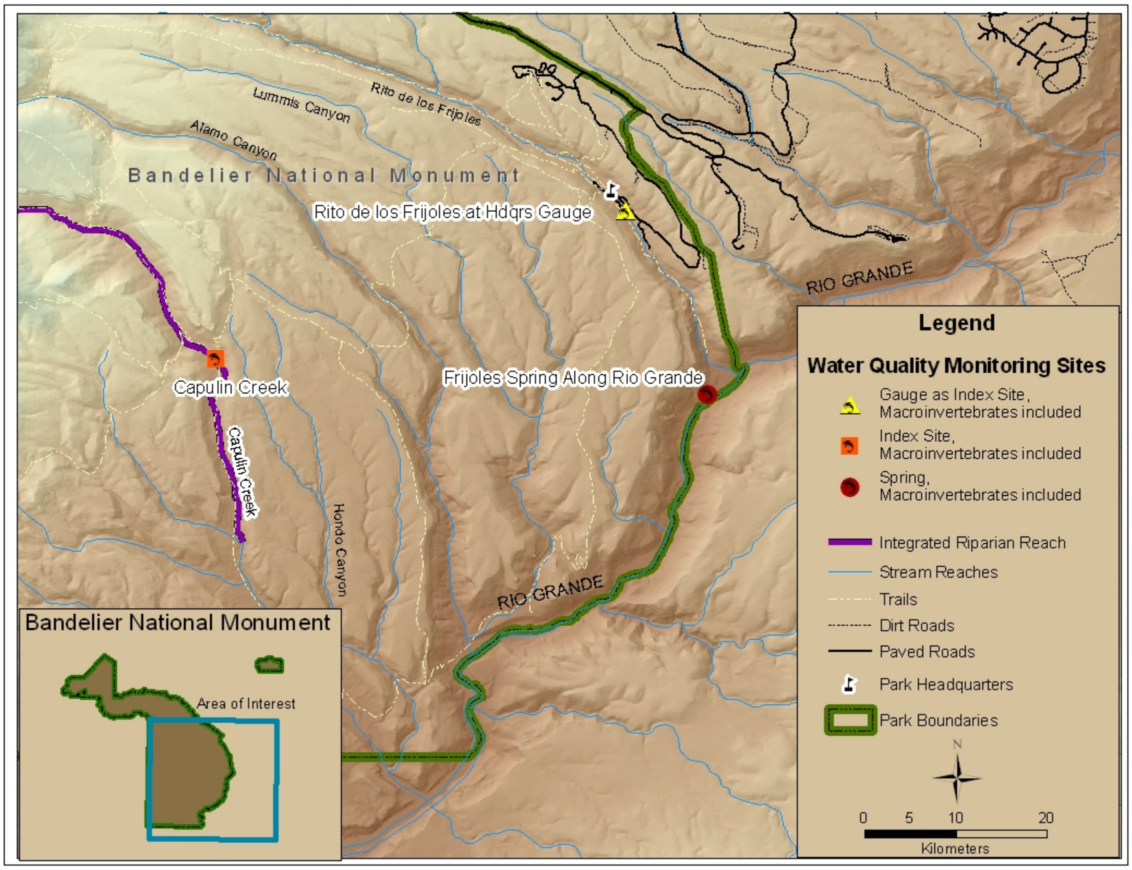


**Figure I1b. Proposed SCPN stream water quality, aquatic macroinvertebrate, integrated riparian, and spring monitoring sites at Bandelier National Monument.**

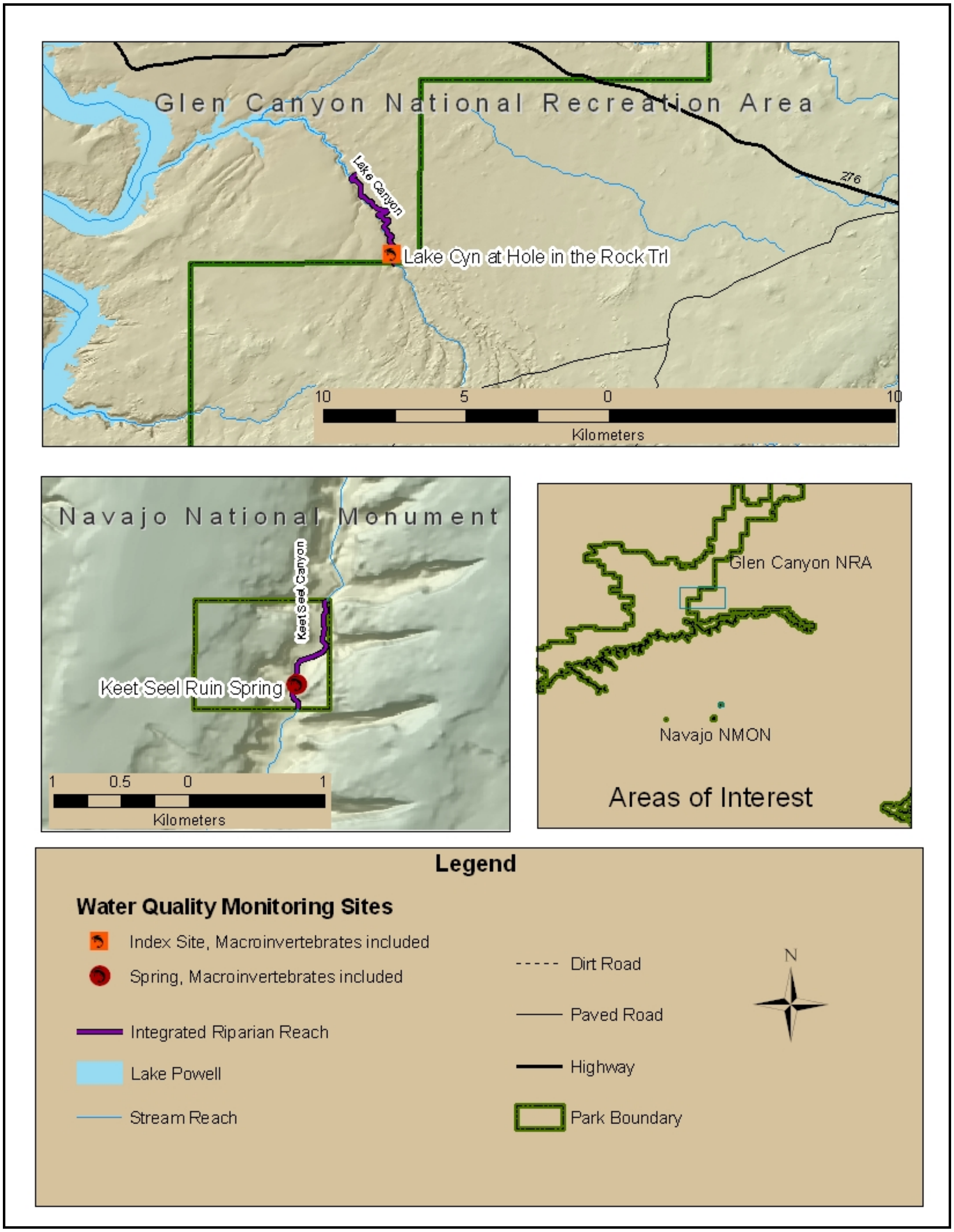


**Figure I1c. Proposed SCPN stream water quality, aquatic macroinvertebrate, integrated riparian, and spring monitoring sites at Glen Canyon National Recreation Area and Navajo National Monument.**

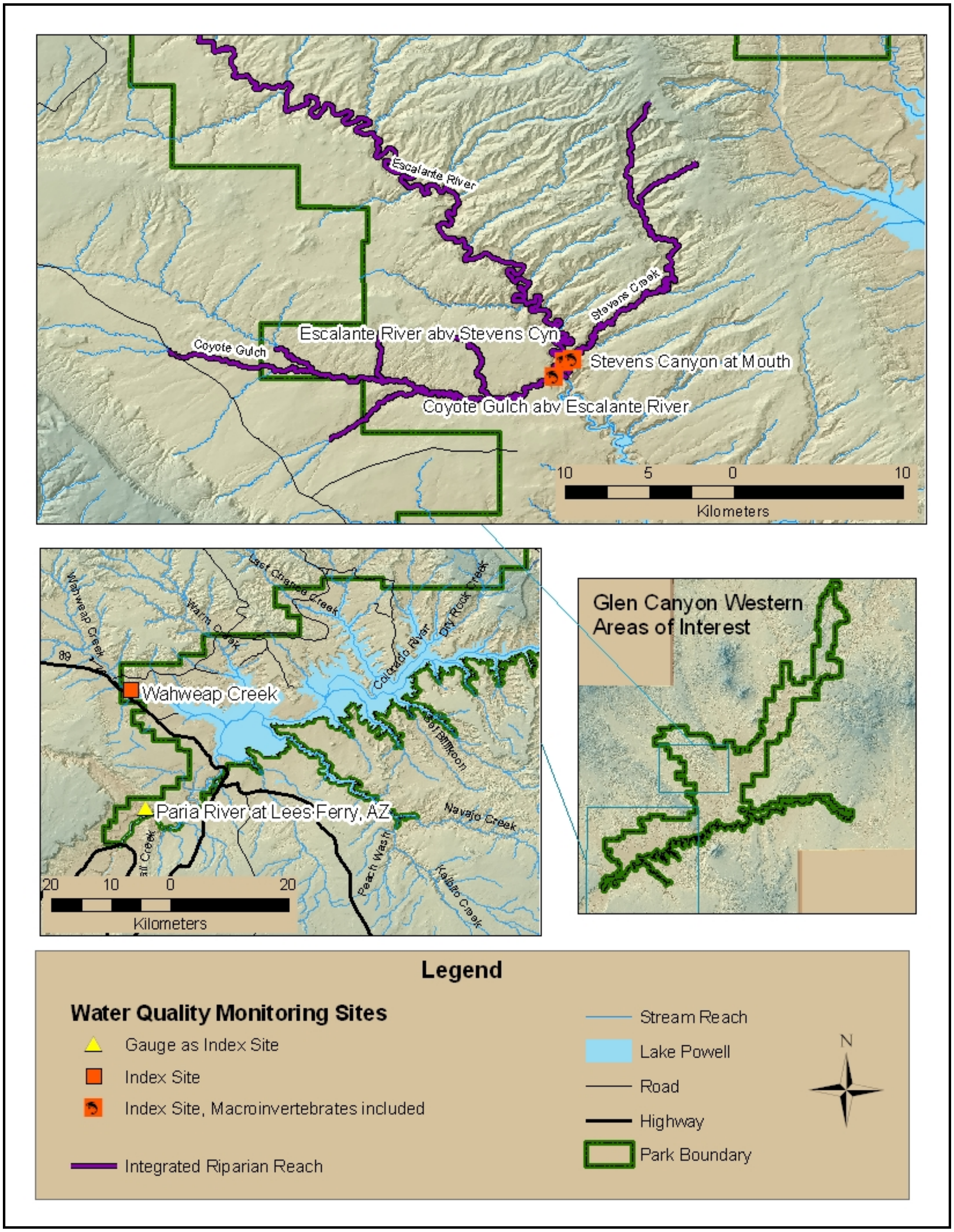


**Figure I1d. Proposed SCPN stream water quality, aquatic macroinvertebrate, integrated riparian, and spring monitoring sites at Glen Canyon National Recreation Area.**

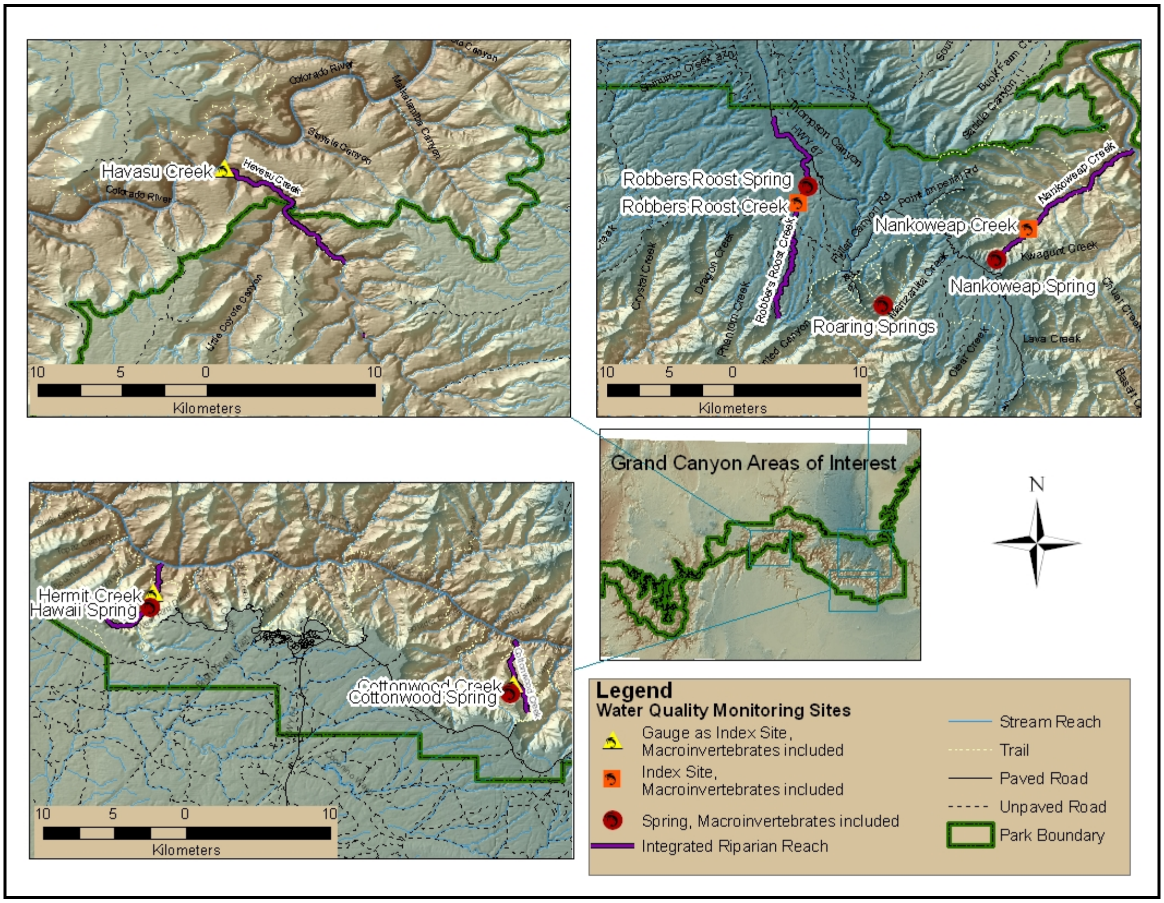


**Figure I1e. Proposed SCPN stream and spring water quality, aquatic macroinvertebrate, integrated riparian monitoring, and spring sites at Grand Canyon National Park.**

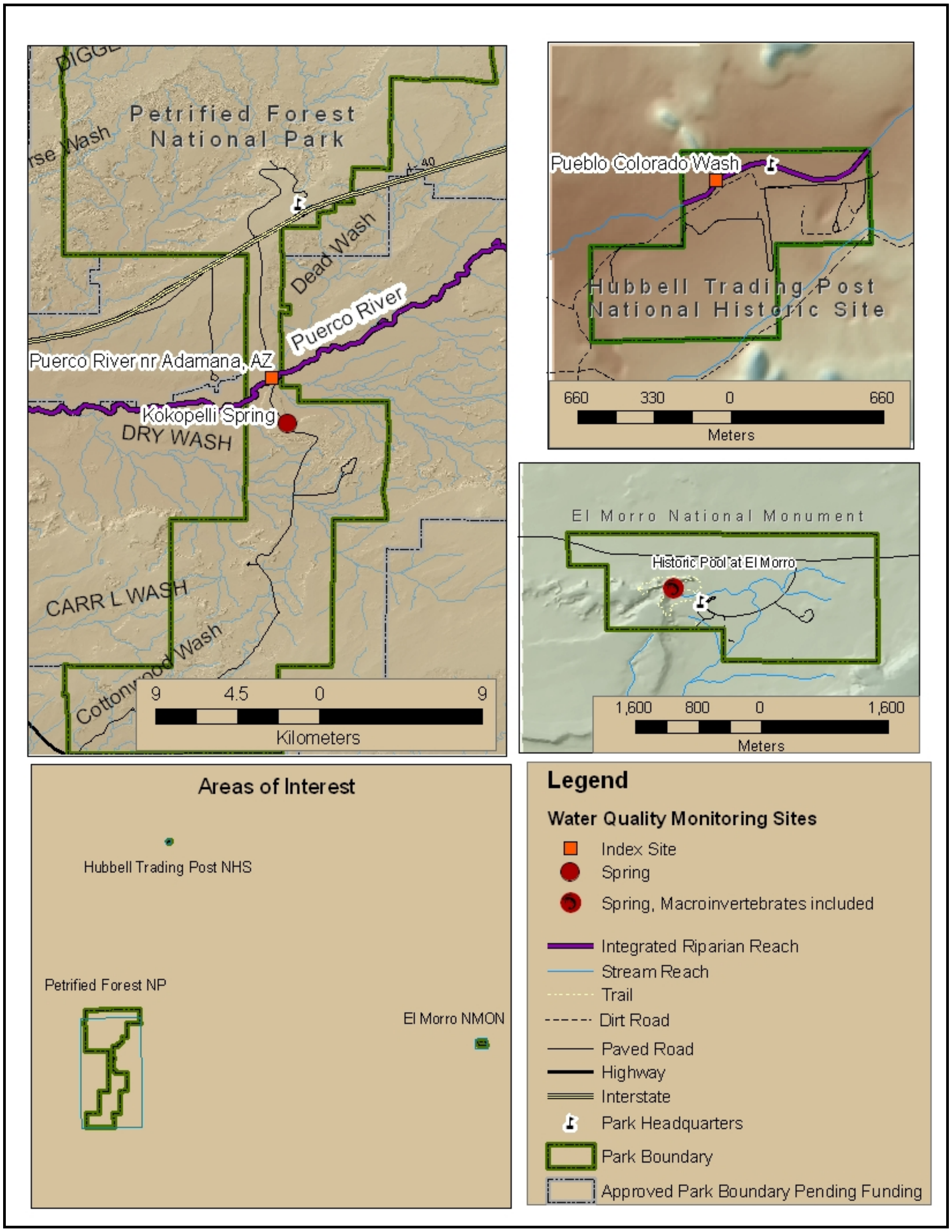


**Figure I1f. Proposed SCPN stream water quality, aquatic macroinvertebrate, integrated riparian, and spring monitoring sites at Petrified Forest National Park and Hubbell Trading Post National Historic Site.**

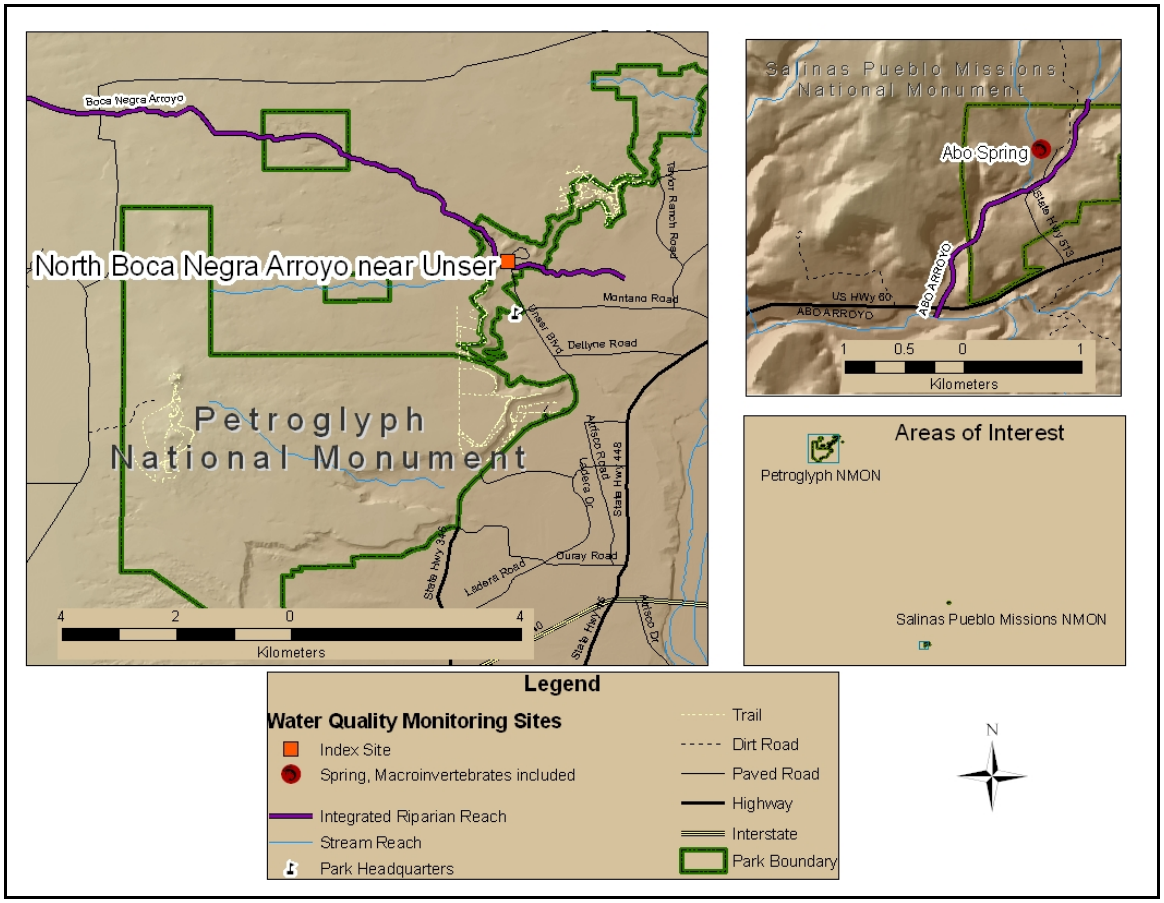


**Figure I1g. Proposed SCPN stream water quality, aquatic macroinvertebrate, integrated riparian, and spring monitoring sites at Petroglyph National Monument and Salinas Pueblo Missions National Monument.**

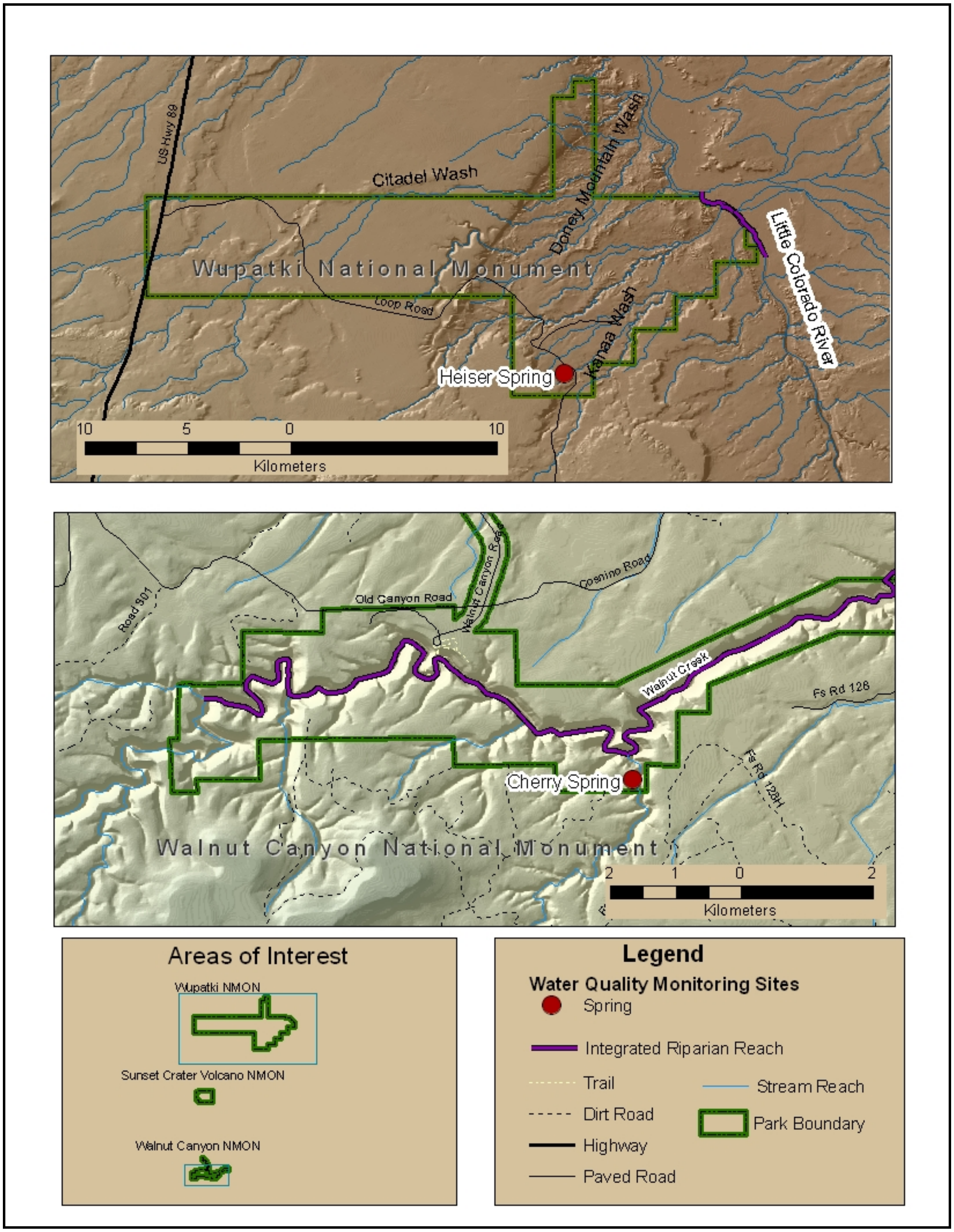


**Figure I1h. Proposed SCPN stream water quality, integrated riparian, and spring monitoring sites at Walnut Canyon and Wupatki National Monuments.**