

DRAFT Report
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This report is a product of activities and discussions by the Research and Infrastructure Committee (RIC) at the January 2005 meeting. The extremely broad nature of “Infrastructure” and the absolute requirement for focus from the other committees before design issues can be addressed seriously in any context, requires that our document be preliminary at this time. In the interest of moving the process along as efficiently as possible, we have provided a relevant framework that should accommodate information from the other committees. We have also given some direction on the specific types of information that we require for a full execution of our charge. With the input just now becoming available in the other science and education subcommittee reports (the subcommittees), we will focus and refine this document before the March meeting. We encourage the other committees to collaborate with us, and to provide all information possible including cost estimates where possible.

Introduction

The RIC is focused on two goals:

1. To distill the specifications from the other NEON Science and Education committees into a cohesive framework that best meets NEON research and education goals (by meeting three).
2. To facilitate access to information about technologies, facilities, infrastructure, and other national networks (collecting biological, physical, chemical and socio-economic parameters) that both exist, and are in the planning stages, that could be applicable to the NEON endeavor. To request assistance from the broader community in this effort. To convey this information to the NEON Science and Education committees, and to the broader science community (by meeting two).

To meet the first goal, we appointed RIC members to liaise, in an iterative manner, between RIC and the other committees through the NEON planning process (Table 1).

RIC representative	Science or Education Committee
<i>Hilary Swain</i>	Sensor/Sensor Networks, Emerging Issues
<i>Stinger Guala</i>	Cyberinfrastructure, Biodiversity
<i>Sandy Andelman</i>	Biodiversity
<i>James Ehleringer</i>	Land Use Change, Emerging Issues
<i>Phil Robertson</i>	Biogeochemical cycles, K12 Education
<i>Stanley Smith</i>	Climate change
<i>Everett Springer</i>	Hydro-ecology
<i>Kathleen Weathers</i>	Invasive Species, Higher Education
<i>Lois Blaine</i>	Infectious Diseases
<i>Steve Kelling</i>	Cyberinfrastructure, Informal Education
<i>Beverly Law</i>	Biogeochemical cycles, Sensor/Sensor Networks

The major categories of our proposed framework for organization and reporting are as follows (a detailed draft outline is given in Appendix 1):

1. Field
2. Analytical
3. Archival
4. Data Analyses and Synthesis
5. Education

1. FIELD

Field Design

The questions posed by the scientific and education committees will determine the specifications for the field design (e.g., types and numbers of field sites, what sorts of biomes to be represented, spatial landscape configuration). Will a finite number of sites with intensive measurement capabilities be most effective, or a highly distributed set of measurements, or both? A formal process will be needed to insure adequate statistical power for proposed field designs. NEON might need to accommodate measurements that span 10^{14} orders of magnitude in size, so scaling of field sites is a key factor to consider. Current ecological research sites vary in size and complexity; for an ecological observatory it will be essential that the field design is at a sufficient spatial and temporal scale and complexity to allow an examination of all the interfaces in the ecosystem (e.g., land/air/water – biotic/abiotic) that need to be measured to address the questions posed. A key component of site selection will potentially be to instrument gradients in the landscape. Different questions may require different or similar gradients; some mentioned in previous reports have been wildland – managed lands – urban; surface watersheds/basins; hydroclimatic regions; groundwater-sheds, air-sheds; food web structures; primary production; land use; and disturbance. The science and education committees could select gradients, such as climate proxies (latitudinal for temperature, longitudinal for precipitation, elevation for both temperature and precipitation), or land-

use proxies (urban to managed to natural ecosystems). For example, it may be that a key question in NEON requires the establishment of a land-use gradient, centered on an urban area of 500,000 or more people (or the largest urban area of a region, if none are that size) in each major biome of the country. Within gradients, we need to know the appropriate scaling for deployment of sampling sites, and how this will be determined. Whether there need to be intensively-instrumented sites located on the gradient is also critical, and if nested manipulation plots need to be established. For example, the Climate Subcommittee question(s) may need a distributed network of baseline soil characteristics and genomics information, manipulations of site water balance or temperature at key points along the gradient, and several intensive sites that examine land-water-atmosphere exchanges of important materials in the landscape. Questions from the Biogeochemistry Subcommittee may require a distributed network of soil characteristics and stable isotope information, manipulations of water and/or nutrient inputs, and intensive analysis of biogeochemical pools and fluxes.

Manipulation facilities need to be carefully identified. We suggest that they be considered from several contexts. Are manipulations to be biological, physical, chemical, or socio-economic? Is it to be a destructive vs. non-destructive manipulation (e.g., controlled burns), or is it to be an amendment (e.g., increased water, species addition, or N-deposition) vs. depletion manipulation (e.g., species removal, rain-out shelter)? Each scientific sub-committee needs to identify the key manipulation experiments that are critical for their science questions. The degree to which the field design for these questions can draw from other long-term and well-supported experiments, or current management manipulations will assist the NEON endeavor, and leverage with other agencies and programs (see e.g., Appendix 2). For example, experimental or manipulation plots that have historically been used primarily for demographic or productivity type data collection, could be further instrumented to yield valuable additional ecosystem data for treatments that in many cases have been ongoing for decades. Awareness of these types of manipulation sites is needed to determine their potential usefulness in a NEON network. Potential manipulation sites may be part of existing national monitoring networks and programs, but subcommittees might also consider whether previous land use history, resource extraction, or other manipulative changes could be incorporated into NEON as quasi-experimental sites.

A final key aspect of field site selection needs to be a determination of accessibility. This determination needs to be made with regard to accessibility for individual researchers, for large educational groups, for potential destructive sampling, for power requirements, and for applicability to various current and emerging technologies and large instrumentation (e.g., fetch for tall tower placement).

Mobile Facilities

We anticipate that a key infrastructure need will be the establishment of mobile facilities that can collect a range of sophisticated data that cannot be collected in a distributed nationwide network. Mobile facilities may be needed for atmospheric, aquatic, and terrestrial environments, and the specific type of mobile facilities need to be determined for each of the questions posed. As part of the infrastructure distillation process we will have to determine if a mobile facility can span a wide variety of data

types, or see if the questions posed suggest more specialized mobile facilities (e.g., for stable isotopes, trace gas fluxes, genomics, etc.) Mobile facilities might be of two broad types: (1) a “swat team” approach in which either a national or regional mobile facility will be available for high-priority data collection, for example, after a major disturbance event; and (2) mobile calibration/maintenance facilities for general support of analytical instrumentation and other infrastructure across the network. Accessibility to sites by mobile facilities need to feedback into considerations of field site design. Requirements for these types of mobile facilities need to be clearly articulated by each subcommittee.

Networks of Sensors

Research infrastructure required for sensor networks will be a major item in the design of the NEON research infrastructure; the requirements for these networks are needed in order to proceed with observatory design. Sensor networks will be used at NEON sites for data collection. This is an area of considerable overlap between the Sensor and Sensor Networking Committee and the Research Infrastructure Committee. The types of networks that are envisioned include but are not limited to physical, chemical, biological, and human sampling with acoustic, visual, electromagnetic, chemical, and radiological sensing techniques. The installation and deployment of these networks is a critical infrastructure issue because of construction requirements need to include features such as communication and power. Individual sensors may range over many orders of magnitude from nanoscales that interrogate the immediate environment to high towers that include a fetch of 100 km or more.

It is understood that sensor network designs are question specific, but it is desirable to provide other groups with the basis for preparing their design. Several examples of a meso-scale sensor array were given as part of the Plenary presentation prepared for the January workshop by the RIC (see RIC PLENARY on the WIKI), including an Evaporation-Transpiration-Recharge Array, an Automated Gas Flux Chamber, and Acoustical Sensor Grid. The SSN Committee is compiling information about sensor technologies that may be applicable to NEON, including those in early development phases that may be more suited to NEON R&D type projects (X-REF to SSN report) The RIC and the SSN will work together to populate this table and seek input from the broader community in this effort. A list of types of information needed to develop the total infrastructure for just one sensing network, regardless of the question being addressed, might include:

- The types of sensors
- How sensors will be deployed – e.g., affixed to species, trees, floating platforms, tower instruments (including the heights if multiple heights are needed).
- The number of sensor arrays at a given location, and within a given field design
- Data collection approach such as data loggers, wireless, computer interfaces, other.
- The power required for the sensors and the infrastructure on which they are deployed, e.g., 110AC, solar panels, and/or battery.
- Site access must be evaluated including e.g. the ability to site major infrastructure such as tall towers or drill rigs.

Existing networks provide substantial information about the maintenance and operations of sensor networks, including issues such as calibration that are important to the life cycle costs and performance. Such issues need to be evaluated so that the design can accommodate replacement of sensors, and the associated costs of these replacement operations. Longevity of many sensors has not been well established.

Logistical Support

NEON infrastructure will be differentially autonomous: some instrumentation will be remotely deployed and low-maintenance with few requirements for resources such as in situ power or roadways. Other instruments will require nearby facilities such as laboratories, cyberinfrastructure, and classroom space. We envisage that observatories will be operational “year around” except in extreme or inaccessible environments. All observatories will require some level of logistical support; it is incumbent on the sub-committees to specify the level of support and pattern of deployment. Logistical support can be categorized into the following areas. Each of these should be considered explicitly when defining instrumentation needs, and needs (both required and desired) should be detailed to whatever extent possible.

1. Accommodations for permanent staff, visiting scientists (including graduate students), educators, student and other groups should be considered separately. Issues include the number of beds and types of lodging required for each type of group, the level of accommodation needed (e.g., long-term visitors require a comfort level different from that of overnight groups), and the availability of dining hall or cooking facilities.
2. Laboratory space on site may be required for long-term instrumentation support, for example, for analytical instrumentation located on-site, for sample preparation, and for visiting scientists conducting in situ experiments or ancillary analyses. Specific laboratory considerations such as wet lab vs. dry lab, specialized power requirements, and the need for access to fume hoods, autoclaves, freezers, cold rooms, microscope rooms, and other support instrumentation should be noted.
3. Classroom space is needed for visiting student groups and other education activities. Some classes will require lab space, and this should be noted along with the type of lab needed (see above). What class and group sizes need to be accommodated?
4. Communications infrastructure is needed for connection to the Internet and other outside networks. The level of connectivity will be important to specify, as is the need for cell phone or wireless networks. This will depend, in part, on local data integration and visualization and analyses needs.
5. Power requirements vary. If instrumentation requires 24/7 grid power then this should be specified. On the other, hand a solar panel or battery will be sufficient in some cases.

6. Vehicle access is another consideration. If roadways are needed to carry instrumentation into a site this should be noted, as well as the frequency. Additionally, vehicle (including boat and airplane drone) storage may be a consideration.

7. Reference collections or facilities for collection and storage at or near the field site may be needed. The need for ultralow freezers or humidity-controlled cabinets should be specified here, as well as other resources such as sample storage (both short-term and archival).

8. Operational support is an additional consideration. Machine shops, instrument fabrication and maintenance areas, and small field laboratories may be useful or necessary.

2. ANALYTICAL (sample processing or calibration)

NEON will establish the infrastructure for the scientific and educational requirements needed to meet long-term national-scale ecological challenges. A NEON-related analytical network can serve two major scientific needs: (a) analytical support for scientific inquiry, research and development, and sampling and analysis infrastructure; and (b) education and training for national-scale monitoring of environmental and ecological change. We recognize that there are many types of analytical facilities that might be considered for NEON-related analytical network, and we do not yet know which facilities will be necessary to address the key questions identified by the science and education sub committees. Here we give some examples (1) of the types of analyses that could be conducted at a national analytical facility in an effort to encourage the other committees to specify their needs. (2) We offer general thoughts and perspectives about the types of analytical facilities and networks of facilities that might serve national needs. (3) We give examples (see box) of two specific examples in analytical technology that illustrate the possible transformational aspects of analytic technologies in NEON.

(1) Types of analyses that a national analytical facility—or facilities—might provide include, but are not limited to: elemental abundance, stable isotope, inorganic and organic compounds, paleoecological, genomics/proteomics, organism identification, remote sensing, GIS, and socioeconomic.

(2) The science and education sub committees need to specify analytical and training needs for their questions, and whether these would be best served by centralized or regionally distributed analytical facilities. These recommendations will enable the RIC to distill requirements into a coordinated network model that might include the following components:

- A national-level **coordination facility or facilities** to serve as the backbone infrastructure for high-level technical training and analytical support services, help with technological innovation, facilitate development of QA/QC procedures, and develop and distribute standard reference materials.

- **Regional analytical facilities** consisting of multiple instruments and related peripherals (networked nationally) to carry out the NEON-related measurements for long-term monitoring, education, and scientific investigation.
- A **comprehensive and multidisciplinary training and education program** to stimulate innovative, interdisciplinary applications of appropriate measurements and ensure that NEON related policy and management decisions founded upon scientific information are made in an educated and informed way.

Although the structure of an analytical network within NEON will be question-driven, one likely model includes the establishment of one or more specialized national coordination facilities, strategically located within the conterminous U.S., which maintain intimate working connections with smaller regional NEON analytical labs.

National Coordination Facility

Should a national coordination facility become a NEON priority based on the scientific questions selected, there are many requirements that need to be considered. The bullets listed below illustrate some of the essential considerations and community benefits of a national analytical facility; they are meant to stimulate discussion.

- A coordination facility could house large and/or expensive instrumentation, with associated preparation and analysis, and high-level technical support, beyond the scope of what can be conducted at the regional scale. For example, this could be accelerator mass spectrometers for ^{14}C measurements or secondary ion mass spectrometers that will enable NEON scientists to measure the isotopic content of individual microbial cells.
- A national analytical facility provides nationwide cross-lab calibration, common protocols, and distribution of relevant standards.
- A coordinated analytical network for long-term monitoring and sampling achieves adoption of accepted methods and standards network-wide.
- The coordination facilities could function as an innovation center for the development of new standard materials, technologies, and analytical procedures.
- The coordination facilities would function as the distributors of high-level technical training, including interdisciplinary graduate and postdoctoral training through centralized short courses that are feasible in a national analytical network setting. Specialized technical training capacities are most efficient when centralized within an analytical network.
- National coordination facilities should be placed where there is excellent airport access, and where there is a large, highly trained technical workforce to attract and retain the skilled individuals needed to build, manage, and operate such facilities.

Regional analytical facilities

In addition to national coordination facilities, the questions driving the structure of an analytical network within NEON may require that smaller NEON analytical facilities be

established across the different NEON regions because fairly routine analytical capacities are required locally near sampling sites. Scientists working on NEON-related projects may require accurate and precise data from an analytical facility with minimal turnaround time. Many analytical facilities already exist across all NEON regions of the U.S. From practical and economic considerations, it might be more logical to enhance regional capacities to meet NEON science goals, rather than centralize all NEON-related analyses into one or a few facilities. Regional labs might carry out the bulk of routine analyses for core NEON-related science, monitoring, and training needs. Regional labs could be encouraged to participate in and even lead innovation, which can be assisted by the coordination facilities. However, very specialized procedures (as examples mentioned above) appropriately would be carried out only at coordination facilities.

Regional labs might be distinct from the existing government, university, and private labs across the U.S, for example, monitoring programs with associated analytic capacities in different federal agencies. We encourage the science and education subcommittees, when specifying their infrastructure needs, to consider how to best leverage these existing analytical capabilities into a broader and more integrated framework. This suggestion is based on several practical realities. First, individual researchers have no great incentive to take on the additional supervision and management needed to support NEON-related activities, which at times would be in conflict with priorities of their own individual research needs. Second, individual faculty and research leaders in government come and go over time; having a sustainable analytical capacity and stationary location would better serve NEON long-term interests. However, placing the NEON regional labs at locations and within institutions where such expertise already exists would benefit the existing labs and NEON related activities. We anticipate that the NNDC will address questions of contractual relationships and incentives to facilitate the synergistic relationship between existing labs and national or regional NEON labs. The central NEON governance and coordination of national facilities and regional NEON labs should have built-in capacities to meet monitoring, research, education, and innovation objectives.

NEON analytical facility as a supplier and user of training.

Training of postdoctoral researchers, graduate students, and technicians who will likely carry out the bulk of the sample collection and analyses within NEON could be greatly aided by a common analytical network. Specialized short courses and workshops on technological aspects of sample collection, preparation, storage, and analysis might be most efficiently organized and managed through a network. Such training could be conducted at key regional labs where unique combinations of expertise might exist or can be routinely assembled, or at the central coordination facility or facilities. In either case, some top-down organization of such training activities within the network would be critical to ensure that the long-term quality of sample collection, analysis, and data interpretation across the U.S. is maintained at the highest levels.

Transformational courses with stable isotopes an example:

The isotope approach has brought together scientists from traditionally separate biological, physical and social science disciplines (<http://ehleringer.net/bio7473.html>). Because of mutual interests in the cycling of key elements and the use of isotopes as a fundamental, interdisciplinary tool, scientists from disciplines as diverse as geochemistry, animal and plant physiology, hydrology, geology, atmospheric science, soil science, geography, and Earth system science are collaborating on cross-cutting research aimed at critical environmental and ecological problems. This transformational role of isotope technology is being expressed further through the emergence of interdisciplinary coursework on isotope applications offered at many universities across the country. Specialized short courses open to students worldwide are now available at several institutions in the U.S. Isotope courses are emerging that are taught from a multidisciplinary perspective and often by several instructors with very diverse academic backgrounds. The grand challenges in the field of ecology are continental and global in scope, and require collaboration among disciplines outside the traditional ecological fields. Integrating information captured by isotope analyses provides a natural platform for transformational, interdisciplinary education on large-scale ecological processes. Through a coordinated, but distributed education and training program, the network would serve to bring this vast interdisciplinary knowledge and experience to those who seek to address NEON-related ecological problems using a stable isotope approach or to those who would like to become knowledgeable about how such information is applied.

Simple identification, an unexpected example of an opportunity for transformational technology development and deployment:

Identification of organisms will be an important component of many facets of NEON, especially work in Biodiversity and Invasive Species. Identification of macro-organisms has traditionally been done in the field with the help of dichotomous keys in field guides or manuals with later corroboration with reference material in physical natural history collections.

Transformative technologies employed in NEON will allow rapid and verifiable identification of macro-organisms in the field through the use of data-rich, highly illustrated, electronic interactive keys with immediate verification through comparison to virtual natural history reference collections. This technology is available now. Within the five-year build-out window of NEON, high throughput automated identification of many types of macro-organisms will become available through the combination of machine learning and high-efficiency image and sound-matching algorithms querying virtual reference collections of high resolution digital images and sound files. Rapid identification and verification through in situ DNA profiling (e.g., fingerprints, sequence series, or barcodes) may also be feasible within the life of NEON.

Micro-organisms will be quickly identified through multiple new high-throughput techniques, including matrix-assisted laser desorption ionization/time of flight (MALDI-TOF) spectral analysis, DNA profiling of various sorts, and mass sample processing using high-volume DNA sequencing techniques

3. ARCHIVAL

Archiving of both data and physical samples will be integral to the NEON effort. Archives provide well-characterized reference collections, data stores, the material needed for reproducibility and verification of research, as well as the basis for transformational and synergistic studies that could not have been conceived at the time of data collection.

Research infrastructure for archiving includes physical facilities for both data and specimens (biological and/or physiochemical). For example, “archival” buildings with environmental control appropriate to the long-term preservation of the specimens being archived are necessary for this effort. These can range from rather simple field libraries to elaborate facilities with level 3 biocontainment laboratories and high-security access systems. Even in the seemingly mundane areas, there has been enormous progress in archiving technologies in both realms and NEON can make use of these. For example, individual environmental monitoring and analysis for each specimen using high volume/low cost commercial inventory management sensors and environmental monitoring systems. Physical repositories for instrument calibration materials (e.g., standard solutions and measured consensus samples) sometimes require elaborate and quickly evolving stabilization or distribution mechanisms.

The cyberinfrastructure subcommittee will address most of the software and data-related issues involved in data archival. We also need this subcommittee to specify the significant physical facilities requirements for electronic data acquisition, curation, and storage on a large scale. For example, active archive stream acquisition facilities (e.g., satellite or sensor data download centers) require satellite dishes, data transfer and storage equipment, and strict environmental controls for housing and maintaining the equipment needed. This is in addition to the human component and software needed for efficient curation and management. In addition to this we bring attention to the cyberinfrastructure subcommittee that archives of biological and physiochemical material in the broad sense will require very specialized cyberinfrastructure in the form of Laboratory Information Management Systems (LIMS), inventory management and access software, and hardware and environmental management software. Working software systems exist, but they have not been integrated to any extent. This integration (which will have to be built) will be key to the success of NEON.

Decisions on the quantity and type of biological and physiochemical materials to be archived will be an important factor in requirements for NEON archiving facilities. For example, some specimens to be used for research are already stored in museums and collections. Other specimens may be more appropriately stored as cloned DNA digital images, rather than as intact biological materials. It may involve transformational science to develop new methods of preserving materials for long-term viability or research potential.

Another factor in considering archival facilities is the regional vs. centralized approach. The issues raised in the Analytical section are also pertinent to archival questions. There

may be significant efficiency in storing and characterizing samples at the NEON sites because of local expertise and a circumscribed scope of research to be carried out at these sites. On the other hand, sharing of materials across sites may require a centralized facility to manage the distribution requirements, addressing both logistical and regulatory issues.

4. DATA ANALYSIS AND INTEGRATION (liaison w/ Cyberinfrastructure)

The NEON research enterprise will require substantial enhancement of facilities and infrastructure available to ecologists to facilitate rapid integration, visualization and analysis of multi-scale, heterogeneous data. It will be crucial to specify whether this capability is needed at a regional or a national scale. (See also Analytical and Archival sections for issues this raises.) This capability will be required during the network and research design phase (e.g., to support development of sampling designs, conduct power analyses, etc.).

Physical facilities requirements for data analysis

The Cyberinfrastructure Subcommittee will address many of the software and data-related issues involved in data analysis, but we also need to specify the significant physical facilities requirements for data analysis on a large scale.

Questions for the Cyberinfrastructure, Science, and Education subcommittees:

- What facilities for data integration and analysis will you require?
- What configuration of facilities and infrastructure will best meet the requirements for the questions posed (e.g., site level, a single centralized facility for the entire NEON network, or some intermediate scale)?
- How frequently and by how many individuals will these facilities be utilized (e.g., daily, weekly, monthly, annually, etc.)?

Infrastructure for the development and maintenance of standards and policies

The ability to rapidly integrate and analyze data will require the development and maintenance of standards and policies for data collection, creation of metadata, and data management, and for intellectual property and data sharing. For example, with any large-scale network, sampling protocols, even when standardized, inevitably will evolve over time. Some changes will result from deliberate, global modifications to sampling designs, whereas other changes will represent *ad hoc* deviations made by individual investigators or individual network nodes as a result of logistical or other local considerations. Regardless, provisions need to be made from the outset to describe the evolution of protocols using structured metadata, including the linkage of these metadata to the corresponding data tables.

Questions for the Cyberinfrastructure, Science, and Education subcommittees:

- What facilities will be required to support the development and maintenance of standard protocols for data collection and for data and metadata management – e.g., will this require face-to-face meetings or training sessions (if so how many people, and what frequency), a web portal, or other sorts of facilities?
- What existing networks have data that will be essential to NEON research to address your question?
- What are the formats and locations for these data?
- When in the course of the research process will data external to NEON be required (e.g., during the design phase, on a regular basis during data collection, or annually or at some less frequent interval)?
- Where will integration of external and NEON data take place (at field sites, universities, synthesis center, etc.)?
- What rate and scope of technology refresh and long term maintenance is needed?

Facilities for Collaboration and Data Sharing

Both the Biodiversity Subcommittee and the Sensors and Sensor Networking Subcommittee identified the need for a “Synthesis Center” facility to support collaboration and synthesis and to promote data sharing. NEON will bring together a diverse community of scientists and educators in ecology and allied disciplines, and will radically expand the nature and scope of collaborations in ecology beyond the current norm. A collaboration and synthesis facility would provide:

- A venue for groups to meet and conduct interdisciplinary planning.
- Facilities, training (e.g., opportunities for junior scientists and educators to collaborate with senior scientists and educators from multiple institutions throughout the NEON network) and support (e.g., analytical consultants) for synthesizing and analyzing large data sets.
- A venue for promoting interactions among the various NEON programs and activities, and for promoting interactions between NEON programs and investigators and those of other science networks.

Such a facility would stimulate new ways of thinking about ecological systems. The needs of NEON for such a facility could be met through support of existing facilities or the development of new ones. Development of a new facility to support collaboration would represent a substantial investment, however, the NSF provides support for several such facilities, including the National Center for Ecological Analysis and Synthesis (NCEAS), the National Evolutionary Synthesis Center (NESCent), and a National Center for Hydrologic Synthesis.

Questions for the Cyberinfrastructure, Science, and Education subcommittees:

- Will NEON needs best be met through support of existing synthesis centers, or are new facilities needed? If existing synthesis centers are sufficient in many respects, what facilities are needed to upgrade these centers.

- If new facilities are needed, how should these be deployed, and what specific facilities and equipment will be needed?

5. EDUCATIONAL

Many of the infrastructure requirements necessary for general research are recognized as important for the educational mission of NEON. For example, the three educational subgroups (informal science education, K-12, and higher education) felt that access to field, analytical, archival, and data analysis applications required for scientific research would be of tremendous value for both formal and informal educational purposes. Access to sensor arrays or data analysis and integration applications at NEON Centers or in classroom settings are essential to successfully fulfilling the NEON's educational goals. The educational committee will need to specify their needs in areas of on-site access, program management, and information technologies, particularly for large-scale citizen science projects. Creating the necessary infrastructure (i.e., access to equipment, data gathering and analysis applications, and program management) to develop citizen science or observation based monitoring programs must be implemented. Moreover, the education committee recognizes that standards for metadata, methodology, data archival and security, and visualization are equally essential to fulfill the educational mission of NEON. Consequently, while it is recognized that the funding sources for education programmatic activities will come from outside of NEON, the scientific infrastructure of NEON must consider and accommodate educational needs at NEON's onset.

Laying the foundation for the incorporation of educational needs into the general research infrastructure at an early stage of NEON's planning is crucial. These needs can be broken into three general areas: on-site, off-site, and information technologies. The rest of this overview will provide a brief summary of the educational requirements of these three areas.

On-site Educational Needs

Considerations within NEON sites for student access are necessary. For example, if many of the NEON sites were located near population centers, this would allow access by a variety of students and more informal science education participants (such as natural history museum programs). For this to occur, these NEON sites will need to have Americans with Disabilities Act (ADA) compliant facilities and provide access to at least a subset of the available sensor arrays, analysis tools, and data visualization techniques available to the scientists at the site. In this way students or individuals participating in museum programs can learn the techniques of collecting environmental sensors and the scientific method of analysis and data visualization.

Off-site Educational Needs

The opportunity for NEON to incorporate community input on scientific research could greatly increase the regional coverage, as well as enhance educational opportunities for users. Considerations in infrastructure design that would provide access to mobile

facilities or resources such as sensor arrays and monitoring applications in classroom or natural history museum settings would be of immense value. This could greatly increase the volume and spatial breadth of data collected and enhance students' understanding of the processes necessary to collect this information.

Information Technologies

The infrastructure requirements necessary, and the potential to engage a vast army of citizens to participate in scientific data-gathering projects across broad spatial scales is enormous. These requirements include program management, web portal (for data gathering and dissemination), and specimen identification. For example, the development of a project application toolbox within the cyberinfrastructure of NEON to allow the creation of citizen science projects for gathering environmental information would have a huge impact on the scope and scale of environmental data gathering. This toolbox would allow a researcher or educator to create a citizen science program that would include keys for identification of organisms, a data collection and management infrastructure, and data visualizations that encompass a broad spectrum of users. For these projects to be successful exacting methodological standards must be implemented in data collection, and infrastructure and engineering must be adequate to the task.

Goal 2. Two main activities were undertaken at the January meeting to facilitate access to information about technologies, facilities, infrastructure, and other national networks that could be applicable to the NEON endeavor. *First*, a brief introduction to some innovative technologies and infrastructures that may be relevant to NEON was presented to other committees (RICPLENARY.PPT on the WIKI). *Second*, numerous sources of information on networks, technologies, and infrastructure were identified.

Although there are some compilations of infrastructure nationwide – such as the field stations “facilities forms” for the Organization of Biological Field Stations (www.obfs.org) and the LTER Site Form (www.lternet.edu), these are not integrated, nor part of a broader assessment of national capacity in terms of instruments, facilities and other research infrastructure. The RIC provided input on a web-based form that has been developed to solicit information about facilities and infrastructure resources across the nation that could be applicable to the NEON endeavor, and to request assistance from the broader community in this effort. We expect that this form will be a means by which existing infrastructure resources can be catalogued and made available to the NEON science and education communities and design consortium. The form and underlying database will be populated by members of the broader scientific community knowledgeable about specific resources familiar to them. We expect this portal and the database produced to be broadly and openly available, through either neoninc.org or the Consortium of Regional Ecological Observatories (COREO) web site.

The RIC also agreed to redouble efforts to engage constituent communities through posts to newsgroups and open solicitation at meetings and through email.

Appendix 1.

1. Field (these are all “on site” but in each case specify the scale at which deployed)

Sites

types of field sites (e.g., geographic needs, density, spatial configuration)

gradients

manipulation facilities

Nature of the manipulation (for example)

Destructive/Non-destructive

Amendment/Depletion

Biological/Physical/Chemical/Socio-economic

level of accessibility (location, e.g., near airport, population centers, public or restricted access, security of site, can do manipulations, etc)

Mobile facilities

types (for example)

Air/Water/Terrestrial

what do you want to do with it?

SWAT (Soil and Water Assessment Tool)

Calibration/ Maintenance

Networks of sensors (also please liaison with sensor group)

types of sensors

deployment

density/spatial configuration//temporal

Physical facilities and logistical support

types of facilities (for example)

accommodation

lab space (teaching or research)

classrooms/meeting rooms

communications (wireless, fiber, phone, cell, radio)

power (grid/in situ)

vehicles/boats/other on site transport

reference collections

operational support (staff, machine shops, etc)

deployment

numbers and spatial configuration (in relation to sites)

2. Analytical (sample processing or calibration)

Scale (for example)

on site

off site (regional/national/integrated network)

Type of analysis (for example)

genomic/proteomic

- isotopic/molecular
- elemental
- organic/inorganic
- identification
- socioeconomic
- Standards (for example)
 - spatial and temporal comparability among instruments
- Physical facilities (for example)
 - containment needs
- Operational support

3. Archival (specify scale at which needed)

- Scale (for example)
 - on site
 - off site (regional/national/integrated network)
- Types of archival material (for example)
 - biological (e.g., specimens, tissues, DNA)
 - physiochemical
 - data (please liaison w/ Cyberinfrastructure)
- Volume
 - static archive
 - active archive stream acquisition facilities
- Standards (for example)
 - spatial and temporal comparability among archives
- Physical facilities (for example)
 - freezers
 - archival buildings (HVAC etc.)
- Operational support
 - level of curation required

4. Data analysis and integration (please liaison w/ Cyberinfrastructure)

- Scale (for example)
 - on site
 - off site (regional/national/integrated network)
- Types of facilities (for example)
 - using internal and/or external data
 - synthesis and analysis
 - standards and policies
 - collaboration and data sharing
- Physical or virtual facilities
- Operational support

5. Educational

- Scale (for example)
 - on site
 - off site (observational network regional/national)

Types of facilities (for example)

- instrumentation
- observational
- community facilities

Physical facilities

- integrate educational requirements into physical facilities specifications under field, analytical, archival, data analysis)

- deployment

- numbers and spatial configuration (in relation to field, analytical, archival, data analysis sites)

- considerations such as ADA, child protection restrictions

- are there other types of physical facilities dedicated only for education?

Operational support

Appendix 2. Draft NEON Resource Registration Form

The table below outlines information that will be collected in order to inform the science and design committees about existing field site, analysis, and collection facilities in the U.S. A web-based form based on this outline will be used to populate a database that will be available for common use. Information will be sought on the geographic location of the resource and the type and characteristics of resources available at that location. A single location, for example, can host a field site, an analytical facility, and/or a biological or physiochemical sample collection. NOTE: this description is not meant to be an exhaustive description of the resources available at any given facility, but rather to represent a first-pass description of the level of facility resources available within a given region.

A. Table 1 – Geographic Registration.

Name of resource:

Location (physical address)

Address1:

Address2:

City:

State:

Zip:

Institutional Affiliation(s):

Web site if available:

Contact name:

Title:

Email:

Phone:

Contributor name (if different from contact):

Relationship to resource (e.g. user, director, staff, etc.):

Email:

Phone:

Owner:

Network Affiliations (if any):

Area available for research

Owned by institution (ha):

Available nearby (ha):

Access Restrictions

Do visitors (foreign or domestic) need security clearance? Yes No

If yes, please describe: [text box]

Experimental Facilities Now in Place

<input type="checkbox"/> Rain-out shelter	<input type="checkbox"/> Flux tower	<input type="checkbox"/> Soil warming	<input type="checkbox"/> Species removal/addition
<input type="checkbox"/> Habitat alteration	<input type="checkbox"/> Nutrient addition	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

B. For Analytical Labs ONLY:

Do you accept off-site samples? Yes No

(do not continue if “No”)

Type of analyses:

<input type="checkbox"/> genomic	<input type="checkbox"/> isotopic	<input type="checkbox"/> elemental	<input type="checkbox"/> organic
<input type="checkbox"/> taxonomic	<input type="checkbox"/> other	Describe Other:	

Capacity (samples/year): <100 <1,000 <10,000 >10,000

Brief description (<50 words): [text box]

C. For Collections ONLY:

Type: Taxonomic Biological Non-taxonomic Physiochemical

Brief description (<50 words; e.g. taxa or sample type, approx. number of specimens, geographic extent. Please also address the databasing extent and access for the collection)
[text box]: