CAP LTER CONNECTIVITY SUPPLEMENTAL REQUEST

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Central Arizona - Phoenix Long-Term Ecological Research Project
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SUMMARY OF PROPOSED EFFORT

The establishment of the Central Arizona-Phoenix LTER introduces many new opportunities and as many new challenges to the extant LTER network. Monitoring and understanding ecological processes as they occur in this dynamic, human-dominated system are already providing exciting insights and refreshing perspectives on the interaction of biological and social systems. Traditional approaches and well-tested methodologies must also be reexamined in light of the vastly altered definition of the ecosystem and the rapidly evolving technologies available to study it. The boundaries of our study site cannot be surrounded by a fence, nor kept free of human "disturbance." Quite to the contrary, our boundaries are rapidly changing, as is the nature of land use, and our virtual "field station" is shared with 2.5 million people who call it home. Rather than a classically defined watershed or geographic region, our field station comprises an ever-changing heterogeneous mosaic of patches tied together by social institutions, highways, and energy-distribution systems. The implications of a virtual field station for data collection, educational outreach, community partners, and connectivity are profound, and so we must rethink the way we operate in the "field."

We propose to raise our intrasite connectivity to a new level, embracing the available technologies and a new genre of participatory research. As an essential step in this direction, the CAP LTER proposes five basic innovations in connectivity:

- Interactive data entry and analysis capability for partner K-12 schools
- Automated electronic data transmission from remote monitoring stations
- Wireless electronic access by field crews for data entry and retrieval
- High-end workstation capability for graduate research laboratories
- Real-time data availability for public outreach

Taken together, these innovations will enhance interactive research participation among K-12 schoolyard ecologists, senior researchers, graduate assistants, community partners, and other involved members of the public.

CAP LTER RESEARCH FOCUS

The CAP LTER is a multifaceted project aimed at answering the general questions, "How does urban development alter ecological conditions and how do ecological conditions affect urban development?" Central to answering these questions is understanding how land-use change is driven by societal decisions, how such change alters ecological patterns and processes, and how changes in ecological conditions further influence human decision making. The overall approach incorporates a hierarchical, patch dynamics model for the metropolis as an ecosystem, with studies and models at smaller spatial scales and lower levels of organization also integral to this work. The CAP LTER also has a significant mission to involve K-12 students in its research questions and has established an educational outreach program, "Ecology Explorers,"

to engage students in the process of scientific discovery. Interconnectivity among data-collection stations within the urban area, the ASU campus, the Schoolyard LTERs, and the broader public is essential to achieve our goals.

Arizona State University provides the interconnectivity for on-campus CAP LTER facilities. A 10-megabit Ethernet connection and soon-to-be-available VBNS connections support the exchange of data among and between the Center for Environmental Studies, CAP LTER analysis laboratories, and data laboratories. We request funds to improve the connectivity between ASU and off-campus schoolyard and field sites. Our Schoolyard LTER program and our long-term monitoring effort within the Primary Production/ Organic Matter and Materials Transport research areas would be significantly enhanced through the additional resources of this LTER supplement.

RELATED FIELD FACILITIES AND PROPOSED CONNECTIVITY

Interactive data entry and analysis capability for partner K-12 schools

The CAP LTER Schoolyard LTER Program. Thirteen elementary, middle, and high schools in the Phoenix metropolitan area are currently piloting our Ecology Explorers program. The schools became involved in our K-12 outreach activities through summer

workshops and internships for teachers sponsored by CAP LTER staff and scientists. These workshops and internships introduced teachers to LTER research that can be translated into classroom activities and long-term research by K-12 students using their schoolyards and backyards. An integral component of the CAP LTER Schoolyard Ecology program is linking students to CAP LTER scientists and to students at other Schoolyard LTER sites.

The Ecology Explorers Web site (http://caplter.asu.edu/explorers) is our primary avenue of interaction with K-12 teachers and students. The site contains three main features: scientific protocols for CAP LTER research projects with data sheets and keys (including a downloadable teacher's guide); an "Ask-a-Scientist" page; and data-entry screens for each protocol. Teachers can obtain the protocols from the Web site or directly from us, but the other features require access to the Internet. In addition to getting kids involved in real scientific research, Ecology Explorers has been developed to meet national and state science education standards.

Students can ask specific questions of CAP LTER scientists and get answers quickly through the Web site's "Ask-a-Scientist" feature. Students can also enter online the data they have collected through the data submission forms. The students will soon be able to view their own data as well as data collected by students from other schools and by CAP LTER scientists. This interactive process encourages students to see the links between science and technology. Ecology Explorers are currently studying ground arthropod populations and bird populations, insect/plant interactions, and completing vegetation surveys. Additional protocols are being developed for climate, water, and pollination studies.

Further development of the Ecology Explorers Web site will enable students to compare data collected at schoolyards across the Phoenix metropolitan area. The Web site will also encourage students to interpret their results and design experiments for presentation at the annual CAP LTER poster symposium. Future Web site features may include a link to other LTER sites, as teachers are interested in having easy access to comparable data from other sites. We are also developing programs with community partners that draw on elements of Ecology Explorers and are planning summer workshops in conjunction with them and CAP LTER scientists.

Teacher and student ability to expand upon the basic data-collection phase of their research depends upon the level of electronic access with the CAP LTER project. Most of our current schoolyard LTER classrooms have Internet capability. However, the ability of three partner schools to participate would be greatly enhanced through upgrading and expanding their current ability to link with our site:

1. Vechij Himdag MishchamakuD School, Gila River Indian Community, Sacaton, Arizona, requires a hub to connect with existing T1 lines and a service provider for three computers for data entry and analysis. This school focuses on science and environmental education for grades 7-12 and relates the curriculum to their local community. Students are participating in the ground arthropod survey and will be participating in several other CAP LTER protocols. They are also learning to use computer, database, and GIS technology. The Gila River community is at the far southern reaches of our study area and in a more remote location than most of our urban schools. Improved computer and Internet access will greatly facilitate their participation in our program.
2. Brimhall Jr. High, Mesa, Arizona, has modems available but requires a server and a service provider to connect with the Internet. This classroom conducts bird surveys and is currently unable to connect to the CAP LTER server to enter their data.
3. Discovery Elementary School, Glendale, Arizona, requires a server to link to an existing T1 line. This classroom conducts bird surveys and is currently unable to connect to the CAP LTER server to enter their data.

Each school will benefit greatly by this increased connectivity, as it will enable them to actively engage students in the process of science. Senior researchers and graduate assistants will also benefit from the additional data that schoolyard ecologists will provide.

Automated electronic data transmission from remote monitoring stations

Primary Production and Organic Matter Dynamics. In the spring of 1998, we initiated pilot projects employing the same design and sites. The design consists of six treatments with three replicates each, for a total of 18 field sites. The treatments are:

1) undisturbed Sonoran desert; 2) agricultural field (alfalfa); 3) xeriscape residential yard developed from desert; 4) xeriscape residential yard developed from agricultural field;

5) mesiscape residential yard developed from desert; and 6) mesiscape residential yard developed from agricultural field. Air temperatures are expected to be lower in a turf (mesiscape) than in the crushed granite (xeriscape) and lower above concrete than above asphalt pavement. Greater plant growth and productivity are expected in the cooler cover types and should correlate with lower air temperatures. Further, soil respiration is expected to be sensitive to site history as well as micrometeorological variables.

A key long-term monitoring program is being designed based on this work. Micromet stations will serve as the primary data-collection devices.

Six micromet stations (consisting of Campbell Scientific 21X and 23X data loggers with air, soil and leaf temperature thermocouples, net radiometers, relative humidity sensors and anemometers) currently measure selected meteorological variables in four residential yard pilot study sites and at two sites on a experimental plot. Some of these units will continue to be located at key long-term core monitoring sites, while others may be moved around for specific short-term experiments. Campbell Scientific data loggers, which store the data in SM 716 storage modules, run the met stations. Real-time connectivity of the micromet stations would enhance the data collection and analysis effort and provide data that will benefit the climate protocol under development for Ecology Explorers. For example, it will be useful for students to access real-time data and compare it with conditions in their schoolyard.

We request funds to: 1) connect these units to the central computer, by means of either radio telemetry or a satellite link; 2) install tipping bucket rain gauges to measure rainfall frequency and amounts; and 3) install solar panels to power these stations, which currently run on batteries that are replaced frequently (weekly to fortnightly).

Transport and retention of materials. This project involves the long-term monitoring of surface water inputs and outputs. The main questions driving this study are: what are the fluxes of key nutrients, salts and trace metals imported to and exported from the CAP LTER urban areas in surface waters (rivers and canals), and what contribution do they make to the whole system mass balance? In addition, what are the spatial patterns of nutrient, salt and metal transport within the urban ecosystem, and how do these fluxes change over time in response to increasing urbanization and variations in climate? To quantify and monitor the annual surface water inputs and exports for the whole CAP LTER study area, a regular water-sampling program has been established at key sites. This sampling program supplements and continues the database assembled by the USGS (NAWQA program).

Analysis of available USGS data shows that the annual loads of most constituents (expressed on a per unit area basis) are invariably larger for basins draining the urban center than those upstream of, and on the fringe of, the urban area. Annual exports of N and P increase three-fold from the fringes to the urban centers and drainage basins on the downstream side of the metropolis, while for trace metals such as Pb there is an eight-fold increase. Preliminary LTER samples have shown that concentrations of nitrate-N, ammonium-N, and phosphate in surface waters increase by an order of magnitude on passage through the metropolis and surrounding agricultural areas. Wide variations in major ion concentrations, pH, and conductivity among study sites appear largely related to differences in the bedrock geology of the drainage basins. Studies directed toward a process-based understanding of nutrient and materials transport and storage within specific urban patch types will be developed in the coming year. Work that the USGS initiated on a series of urban sub-basins will be continued by LTER in collaboration with USGS scientists. We intend to combine patch-specific studies of nutrient dynamics with data on transport in urban runoff, as a means of linking the "patch-based" and "whole system mass balance" approaches. One major unknown in the mass balance calculation is the importance of inputs via atmospheric deposition. No monitoring of rainfall amounts and chemistry is currently carried out in the valley. Moreover, the National Atmospheric Deposition Program currently has no sites located in an urban area.

The following research areas would benefit from upgrades. Such real-time connectivity would significantly advance our data, collection, and analysis capability, with the value-added benefit of providing integrative opportunities for K-12 students working with the climate and water protocols currently under development for Ecology Explorers.

1. Atmospheric deposition monitoring sites. We are establishing a network of 10 sites to monitor the amount and chemistry of atmospheric deposition at key locations around the CAP LTER study area. While we are co-locating this equipment at seven Maricopa County/ADEQ air quality monitoring sites and at two National Atmospheric Deposition Program/National Dry Deposition Network sites, the former seven sites currently have no rainfall monitoring equipment. We propose to purchase and install tipping-bucket rain gauges and data loggers for these sites and establish telemetry links at five sites that represent the variability in rainfall patterns across the study area.

2. Stream flow continuous monitoring. For the surface water component of the CAP LTER nutrients mass balance, as well as study of climate-induced temporal changes in storm transport of nutrients and materials, we are monitoring water chemistry at seven sites with continuous flow and five storm flow sites, directly above, within, and downstream of the Phoenix metropolitan area. These 13 sites are co-located with USGS/Maricopa County Flood Control District gauges from which continuous flow data can be obtained and used with our water chemistry data to: a) estimate surface water fluxes of key nutrients and salts and b) monitor long-term changes in surface water quality upstream and downstream of the city. An important component of this work is the ability to compare long-term changes in fluxes and water quality from urban watersheds with an undeveloped "control" desert watershed. This long-term control site is provided by Sycamore Creek. However, even though there is a long-term water quality data record, the only flow gauging data available to date is from a USGS station, a significant distance downstream from the study site. No gauging instrumentation is installed in the middle and upper reaches of the catchment – a necessity if data from urban watersheds and canals are to be compared with pristine desert watersheds of similar sizes. To accurately quantify the storm exports of

nutrients and materials from this flashy desert watershed requires a continuous monitoring of flow.

We propose to install continuous flow monitoring equipment at:

- a small tributary in the upper reaches (Mesquite Wash). This site is the focus of new research aimed at studying the terrestrial-stream linkages in a desert watershed. This site will require a data-collection platform, consisting of a datalogger and satellite telemetry to be attached to the ISCO storm flow sampler currently being installed there.
- the middle reaches of Sycamore Creek main stem. This site is where the majority of long-term data are available for the watershed. Once accurate flow measurements are obtained, they could be correlated with the existing continuous flow record from the USGS station located much lower down the main stem of Sycamore Creek, just before it joins the main Verde River (a major tributary of the Salt River that flows through Phoenix). Intercalibration of flow data from the two stations would provide a means of accurately back-calculating nutrient fluxes for the long-term water chemistry data set held at ASU. Due to the larger size of the main Sycamore Creek channel and its capacity for infrequent but high-storm flows, a full USGS-grade gauging station is required. This station will require a continuous flow gauge, cable way to measure high-flow events, and shelter to secure and house equipment. Most importantly, installation of telemetry equipment to relay real-time flow data back to the ASU/CAP LTER server would allow for much better planning of sampling campaigns during periods of heavy rainfall and storm flow conditions.

Wireless electronic access by field crews for data entry and retrieval

Taken together, a cellular phone with CDPD (circuit switched cellular and packet data) capability, cellular modem, and an inexpensive laptop computer offer a powerful and portable remote data-collection kit. Four such kits will provide the CAP LTER field teams with sophisticated and reliable technology to efficiently record and transmit data on the spot. These kits, along with a Proxima optical projection device, will be available on a sign-out basis to Education Liaison staff and graduate research assistants to use in partner schools and informal education centers, literally bringing field research to any classroom or community group. A graduate research assistant will provide programming expertise to build the necessary interface between the data collector and the data repository.

High-end workstation capability for graduate research laboratories

Graduate research assistants, along with education and community outreach professionals, will be key in disseminating CAP LTER research results to the K-12 and undergraduate students, community partner organizations, and the audiences they serve. The availability of a high-end workstation will allow for the complex multitasking efforts and specialized software applications that go into the production of integrated GIS-based maps and other graphics to display research results and produce graphic large-format posters for Schoolyard LTER use. The generation and analysis of real-time data is accompanied with issues of data storage, data manipulation, data analysis, and data interpretation. We believe that one such workstation will complement the existing hardware and software in our data and GIS labs and enhance our ability to interconnect various components of our data network.

Real-time data availability for public outreach

The real-time collection of climate and surface water data, combined with the enhanced capability to collect other real-time data through wireless remote field kits, will build a base for methods to display and disseminate research results and data to the wider public. Developing and implementing climate and water protocols for Ecology Explorers will also serve this goal. The ability of LTERs to communicate important research questions and research results will help citizens and policymakers to better understand and evaluate complex environmental and ecological issues. Greater connectivity among and between parts of our urban LTER will contribute to a broader and more inclusive mission for the LTER program.

IMPLEMENTATION PLAN

The CAP LTER is poised to expand its capabilities in the directions described. The proposed connectivity enhancements will be implemented as soon as possible after notification of the award. To insure success, some components will be phased in so that data transmission can be thoroughly tested and quality control procedures in place prior to full implementation.