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The State of the CESU Network

Introduction

THE COOPERATIVE ECOSYSTEM STUDIES UNITS (CESU) NETWORK was founded on 22 June 1999. Six federal agencies and 20 universities were founding partners, organized into four of an envisioned national network of 17 CESUs. Five years later, in July of 2004, the seventeenth and final CESU was established. The CESU Network now includes 13 federal agencies, 181 universities and other partners, and full national coverage from Puerto Rico to Guam, from northern Alaska to southern Florida. Hence, an assessment of the "state of the Network" may be both timely and useful.

Even by contemporary standards, it is a young network, and young networks emerge with a distinct history. The Internet is an extraordinary example. In early 1969, the first ARPANET link was established between computers at the University of California–Los Angeles and Stanford University (RAND 2004). A month later the University of California–Santa Barbara and the University of Utah became additional nodes, followed by the RAND Corporation. By late 1972, there were only 37 nodes on ARPANET, and its future was unclear. In 1983, the network split into separate civilian and military components, and the term "Internet" was soon applied to the civilian sector. By 1999, the estimated size of the Internet was close to 1 billion documents (Barabási 2002). By 2002, the network had linked over 100 million computers in 250 countries, and had annually doubled in size for ten consecutive years (Buchanan 2002).

In part due to the importance and ubiquity of the Internet, as well as to advances in physics, systems ecology, molecular biology, organizational sociology, information technology, geographic information systems, and other fields, the study of networks has grown considerably in recent years. One way of addressing the state of the CESU Network is to learn and borrow from the insights emerging from this research. What can network science tell us about CESUs? And which characteristics of networks—including their growth, maturation, adaptation, and trajectory—are relevant to the CESU Network?

The purpose of this article is to provide one assessment of the state of the CESU Network. First, a primer on CESUs is presented, outlining their key features. Second, several network science concepts are described and applied to the CESU Network. Third, the growth and maturation (key network science concepts) of

CESUs are discussed. Finally, a set of future challenges facing the CESU Network are identified.

A Primer on CESUs and the CESU Network

Federal resource management, environmental, and research agencies, along with the nation's universities, share several science-related goals: high-quality research and scholarship, usable knowledge for managers, responsive technical assistance, continuing education, and cost-effective research programs. Cooperative Ecosystem Studies Units represent an innovative approach to achieving these goals. *Cooperative* emphasizes that multiple federal agencies, universities, and other institutions are collaborative partners with substantial involvement in CESUs and their activities. *Ecosystem studies* include the full range of biological, physical, social, and cultural sciences and fields of applied scholarship needed to address important resource issues and support science-based decision-making. *Resources* include both natural and cultural resources associated with federal lands and waters.

Each CESU is established through a formal competition, and implemented through a unified cooperative/joint venture agreement between the federal agencies and the nonfederal partners. Importantly, there is *no* lead federal agency for an individual CESU or the overall CESU Network. Each CESU functions as a "virtual" organization, with agencies and partners linked together through the formal CESU agreement. All CESU agreements follow a similar template reviewed and approved by the Department of the Interior (DOI) Solicitor's Office, other federal agencies, and university administrations and legal counsels. A consistent, reduced overhead rate is applied across the CESU Network, except for agencies that have specific statutory limitations.

A host university is the primary contact for each CESU. Partner universities and other institutions (such as non-governmental organizations, state agencies, and others) add breadth and depth in expertise and resources. At least one, and often more, of these partners must be a minority institution. The host and partners provide space, access to facilities, basic administrative support, and the skills and expertise of their faculty, staff, and students. Federal agencies contribute scientific staff as appropriate to their agency mission—some may be research scientists, while others may be science administrators or resource/environmental management professionals.

Federal agencies also contribute additional administrative support, and provide funds for specific research, technical assistance, and education projects. Projects are undertaken with substantial involvement of (and benefits to) both federal and nonfederal partners. A federal managers committee provides field-based advice and guidance to the CESU. Each federal agency follows its own appropriate laws, regulations, and policies regarding participation in CESU projects and activities. Local option, flexibility, and decision-making are encouraged. At the same time, participation in a common agreement provides new opportunities to identify shared needs and priorities, leverage funding, and improve efficiency through collaboration. Figure 1 highlights the key elements of each CESU.

CESUs are organized around a series of general biogeographic regions. A map is provided as a special insert in this issue of *The George Wright Forum*. The map shows the full complement of CESUs, host universities, and partners as of September 2004. Each CESU has local and regional responsibilities, as well as opportunities to participate in projects at a national level. Together,

Multiple Federal Agencies	• each CESU includes more than one federal agency
Host University	• each CESU has a lead institution • host provides leadership, administrative support, and space
Partner Institutions	• each CESU includes other universities, state agencies, and NGOs • each CESU includes at least one or more minority institutions • partners expand expertise and skills of a CESU
Role and Mission Statement	• describes the research, technical assistance, education, and other expertise the CESU is especially qualified to provide for region and nation
Managers Committee	• committee of local and regional managers from participating federal agencies provides advice and guidance on CESU priorities and activities
Strategic and Annual Work Plans	• each CESU develops plans for improved research, more usable knowledge for managers, and reduced costs

Figure 1. Key elements of CESUs.

the individual CESUs form the CESU Network. The Network is guided by a CESU Council, authorized through a memorandum of understanding amongst the participating federal agencies. The CESU Council includes representatives of each of the participating federal agencies. The Network is led by a national coordinator appointed by the Council.

The CESU Council establishes the mission, scope, and broad policy objectives of the CESU Network. The mission of the CESU Network is

> to promote, conduct, and provide research, technical assistance, and education services nationwide in support of the missions of participating federal agencies and their partners concerning natural and cultural resource management on federal lands and waters (CESU Network 2003b: 5-6).

In this mission, *research* is defined as the creation of new knowledge, *technical assistance* is the application of existing

knowledge, and *education* is the transfer of knowledge. In many cases, these activities may be combined in a single program or project.

Research activities of the CESU Network are both disciplinary and interdisciplinary, combining the skills and expertise of university faculty and other experts with those of federal managers and scientists in ways that create high-quality science and scholarship and deliver usable knowledge. Both long- and short-term research projects, appropriate to each agency's mission, are conducted through the CESU Network. Multi-agency projects are encouraged. For example, a series of related projects has been completed through the Rocky Mountains CESU to assess the impacts of heavy metals contamination of soils at Grant–Kohrs National Historic Site and nearby Bureau of Land Management (BLM) lands.

Technical assistance by the CESU Network is essential to meeting the missions of participating federal agencies and their partners. Technical assistance applies existing theories, techniques, and research results to solving (or mitigating) specific resource management problems. For example, a project of the North Atlantic Coast CESU is being conducted with the National Park Service (NPS) to create a GIS-based automated coastal change analysis "toolbox" for managers and researchers to use in analyzing coastal geomorphologic data.

Education through the CESU Network includes the professional development of federal resource managers and other employees through workshops, conferences, training sessions, and degree programs, as appropriate. It also includes the training of graduate and undergraduate students through their participation in CESU projects, and educational programs designed for citizens (including, but not limited to, environmental education, resource interpretation, and public science education). For example, a project with the Pacific Northwest CESU is being conducted with Nez Perce National Historical Park to develop a "parks as classroom" curriculum module related to ethnogeography.

Research, technical assistance, and education are the primary tasks of each CESU. Importantly, the scope of CESUs includes both natural and cultural resources, all of the relevant disciplines, and the delivery of services to both natural and cultural resource managers. Hence, the mission of the CESU Network is both ambitious and practical, expansive in scope while specific in purpose, and reflective of the skill and expertise residing in federal agencies, the nation's universities, and other partners.

The Science of Networks

As Albert-László Barabási describes in his book *Linked: The New Science of Networks* (2002), the emerging science of networks owes much to a branch of mathematics called "graph theory." Whatever the identity and nature of nodes and links, for a mathematician they form the same thing: a graph or a network. Computers linked by phone lines, molecules in our body linked by biochemical reactions, companies linked by trade, islands linked by bridges, and organizations linked by cooperative agreements are all examples of networks. The CESU Network is built of nodes (federal agencies, universities, and other partners) as well as linkages (membership, participation, and ongoing projects in one or more CESUs).

Research into the behavior of networks has discovered several unusual characteristics. There are three distinct kinds of network architecture, and these structural kinds ("topologies," in mathematics) apply

to a wide range of networks. Figure 2 is taken from Paul Baran's classic 1966 paper on distributed communication networks (Baran 1966). Baran, a RAND researcher, was investigating the capacity of communication networks to survive nuclear attack. (The paper begins simply with "Let us consider the synthesis of a communication network which will allow several hundred major communications stations to talk with one another after an enemy attack.") Baran argued that a centralized network was more vulnerable than a decentralized or distributed network, and that each type of network had unique structural properties.

One of these properties, shared by complex decentralized or distributed networks, has been labeled "small-world" behavior (Watts and Strogatz 1998; Buchanan 2002). These networks allow for individual nodes that are seemingly far removed to be linked together through only a few other nodes (each being a "degree of separation"—as in the Internet game The Oracle of Kevin Bacon, or the Erdös number phenomenon among mathematicians, or the interconnectedness of ecosystem food webs; see Barabási 2002; Solé and Montoya 2000). Another property is that many of these complex networks exhibit "scale-free" structures—with most nodes connected to just one or a few other nodes, and a few nodes connected to many other nodes (it is called "scale-free" due to the shape of distribution of links per node).

Figure 3 shows the current network architecture for three western CESUs, with the host universities as highly connected nodes. The CESU Network is clearly a decentralized, scale-free network, with benefits of "small-world" degrees of separation—i.e., a large number of agencies and universities linked together through minimal bureaucratic layers (degrees of separation). An example is the ability of federal agencies at the local or regional level to send funds for collaborative projects directly to any partner in a CESU.

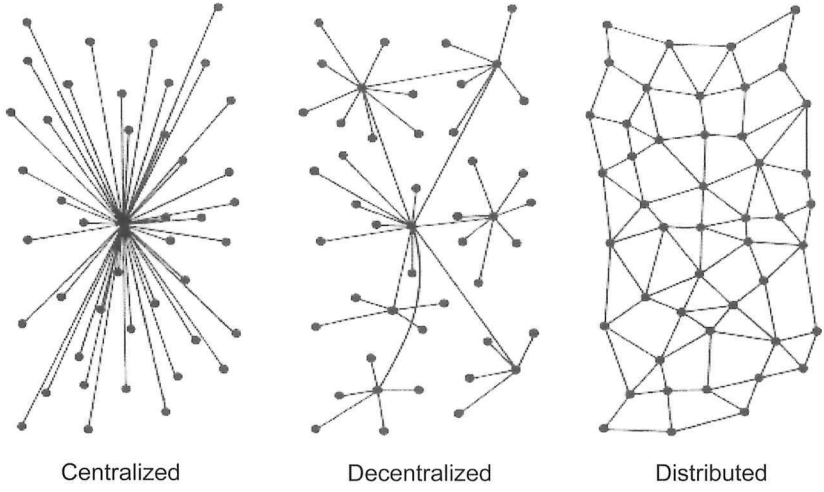


Figure 2. Centralized, decentralized, and distributed networks (adapted from RAND 2004).

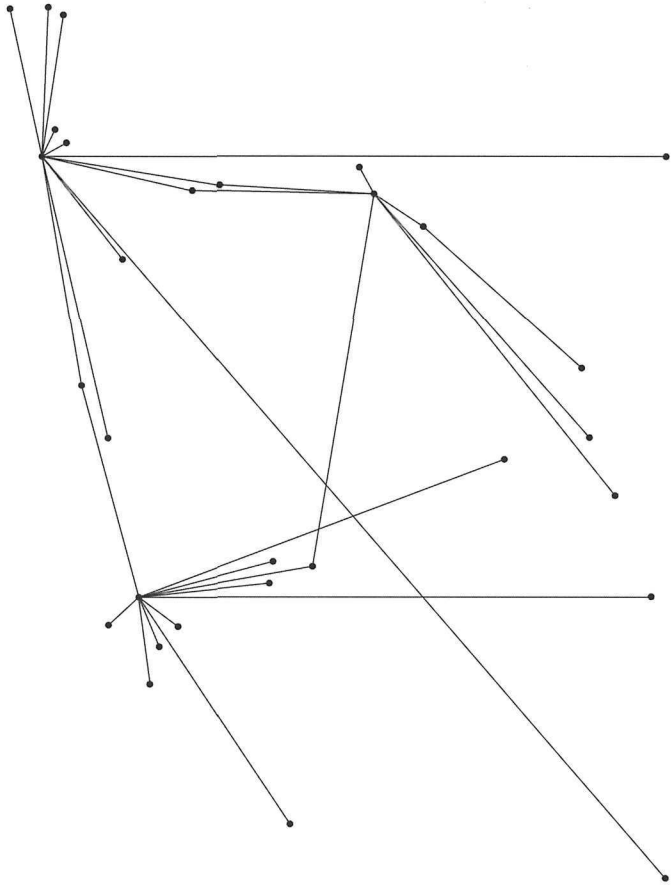


Figure 3. Network architecture for three Western CESUs.

These structural properties change as networks grow and develop. Hence, the emergent growth history of networks is important. Most networks grow one node (with resulting new links) at a time. For example, if only a few connections are randomly added, the nodes continue to pair up steadily. If links continue to be added, the nodes will eventually connect in pairs to each other, forming clusters of several nodes. (A CESU could be conceived in graph theory as a cluster of nodes, with each university and partner organization considered a node.) But when enough links are added ("enough" varies by kind of network), something dramatic happens—one can quickly navigate from one node to any and all others along the links between the nodes.

Mathematicians call this maturing phenomenon the emergence of a *giant component*. Physicists call it *percolation* and describe the change as a *phase transition*, as in the moment in which water freezes. Sociologists will explain that the subjects have formed a *community*. Regardless of

terminology, the disciplines agree that at some point in network development something special happens. Before, there were isolated, disparate clusters of nodes; after, the clusters are joined, integrated, and functioning in new ways.

Perhaps the completion of the CESU Network's basic structure signals a phase transition in the CESU Network. As such, an assessment should touch on at least three network characteristics: growth, maturation, and trajectory (future prospects).

Growth (A CESU History)

As described earlier, the historical development of an emergent network is important to understanding current network structure and properties. A formal administrative history of the CESU Network by a professional historian has not been written, though it has been proposed (O'Brien, personal communication, 2003). What follows is a recollection by ourselves as participants, with all the strengths and weaknesses such participant observations provide.

In early 1996, considerable reinvention of park-related science within the Department of the Interior was underway. NPS, U.S. Fish and Wildlife Service (USFWS), and other DOI agency scientists were transferred to help staff the new National Biological Service (NBS, later to become the Biological Resources Division of the U.S. Geological Survey). The future of Cooperative Park Studies Units (CPSUs), initiated in the 1970s, was unclear. The need for expanded partnerships between NPS and the nation's universities was increasing in response to the complexity of resource problems faced by the agency and the need for access to a broad range of scientific expertise. Informal and formal proposals for action were developed; an example was the formal proposal to restructure the CPSU system into a series of multi-agency, multi-university cooperative study units (each with a host and partner structure) included in the NPS plan for its social science program (NPS 1996). A stand-alone proposal entitled "A Conceptual Proposal for Restructuring CPSUs—Cooperative Protected Area Study Units" included both NPS and NBS participation, and expanded the idea to all relevant disciplines.

By August 1996, the concept had been further developed in a more formal proposal entitled "Science for Management in the 21st Century: A Proposal." It was in this document that the term "Cooperative Ecosystem Studies Units" was first used. The proposal was presented to the DOI secretary and DOI Science Board in September 1996; it had been expanded to include science support for other DOI bureaus and selected federal agencies outside of the department. At the direction of the secretary and assistant secretary for water and science, a formal CESU Implementation Working Group was formed in February 1997. The initial working group included representatives of the NPS, USGS, USFWS, BLM, U.S. Bureau of Reclamation (USBR), U.S. Department of Agriculture Forest Service (USDA FS) and Environmental Protection Agency (EPA). The working group met throughout 1997, refining the CESU concept; by November 1997 both the plan for a CESU Network and a strategy for its construction were in place.

A key element of this strategy was to build the CESU Network in a series of phases (called "rounds of competition"), following the principles of adoption and diffusion of innovations. The study of adoption and diffusion has a long tradition in sociology, and it has been applied to a wide range of innovations, from agricultur-

al practices, to the acceptance of new pharmaceuticals by doctors, to new industrial processes. E. M. Rogers' *Diffusion of Innovations* (1983) provided the group a useful framework for building the CESU Network. As Rogers noted, there are several characteristics of an innovation that will significantly influence its adoption. These include:

- *Relative advantage*: the degree to which an innovation is perceived as better than the idea it supersedes.
- *Compatibility*: the degree to which an innovation is perceived as being consistent with existing values, past experiences, and needs of potential adopters.
- *Complexity*: the degree to which an innovation is perceived as not difficult to understand and use.
- *Trialability*: the degree to which an innovation may be experimented with on a trial basis.
- *Observability*: the degree to which the results of the innovation are visible to others.

Rogers suggested that there are different classes of adopters—from "innovators" to "late-adopters"—and each class may have a different set of reasons to adopt an innovation. Figure 4 shows that typical diffusion patterns follow an "s-curve," with change agents attempting to influence innovators and opinion leaders, and later adopters joining in as the uncertainty of the innovation declines and the rate of adoption slows. While current research suggests that the innovation process is even more complex than Rogers described, the basic prin-

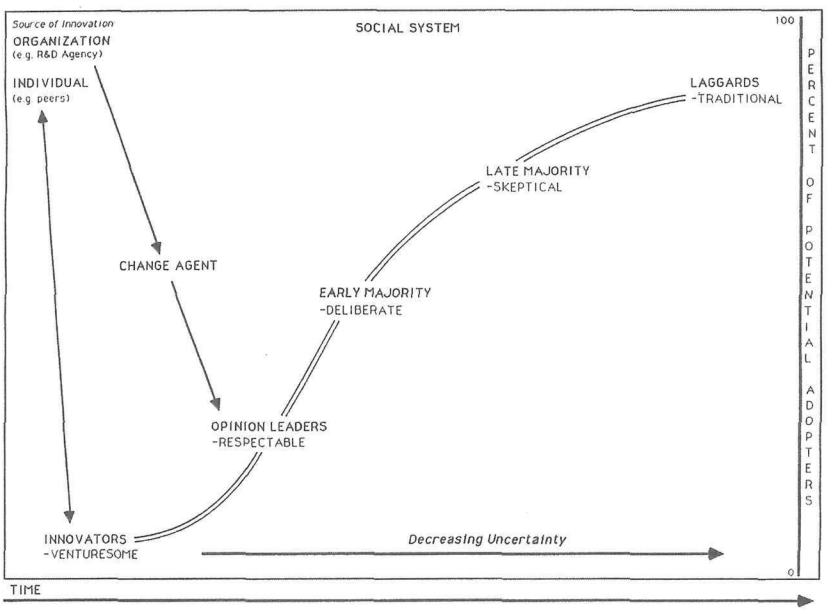


Figure 4. The typical adoption-diffusion curve (adapted from Rogers 1983).

ciples were helpful in organizing (and communicating) the strategy for constructing the CESU Network.

The working group focused on developing an overall network plan and four pilot CESUs, targeting early adopters within interested agencies. A detailed introduction to the CESU Network ("CESUs: An Introduction") was prepared, closely adhering to Rogers' principles. Figure 5 highlights the features of the proposed CESU Network linked to Rogers' characteristics of successful innovations. By November 1997, agency and solicitor review of the first request for proposals (authorized under each agency's authorities to enter into cooperative agreements) had been completed and the request for proposals distributed. Four bioregions were targeted: Colorado Plateau, North Atlantic Coast, Rocky Mountains, and Southern Appalachian regions. Proposals were due in February 1998.

As the proposals were being reviewed,

Relative Advantage

- delivery of research, technical assistance, and education in full range of disciplines
- expansion of science-related expertise available to federal agencies

Compatibility

- evolution of successful strategies
- complement to existing research programs

Complexity

- established under common, unified cooperative agreements
- organized as decentralized network architecture
- independent initiative encouraged—"local option"

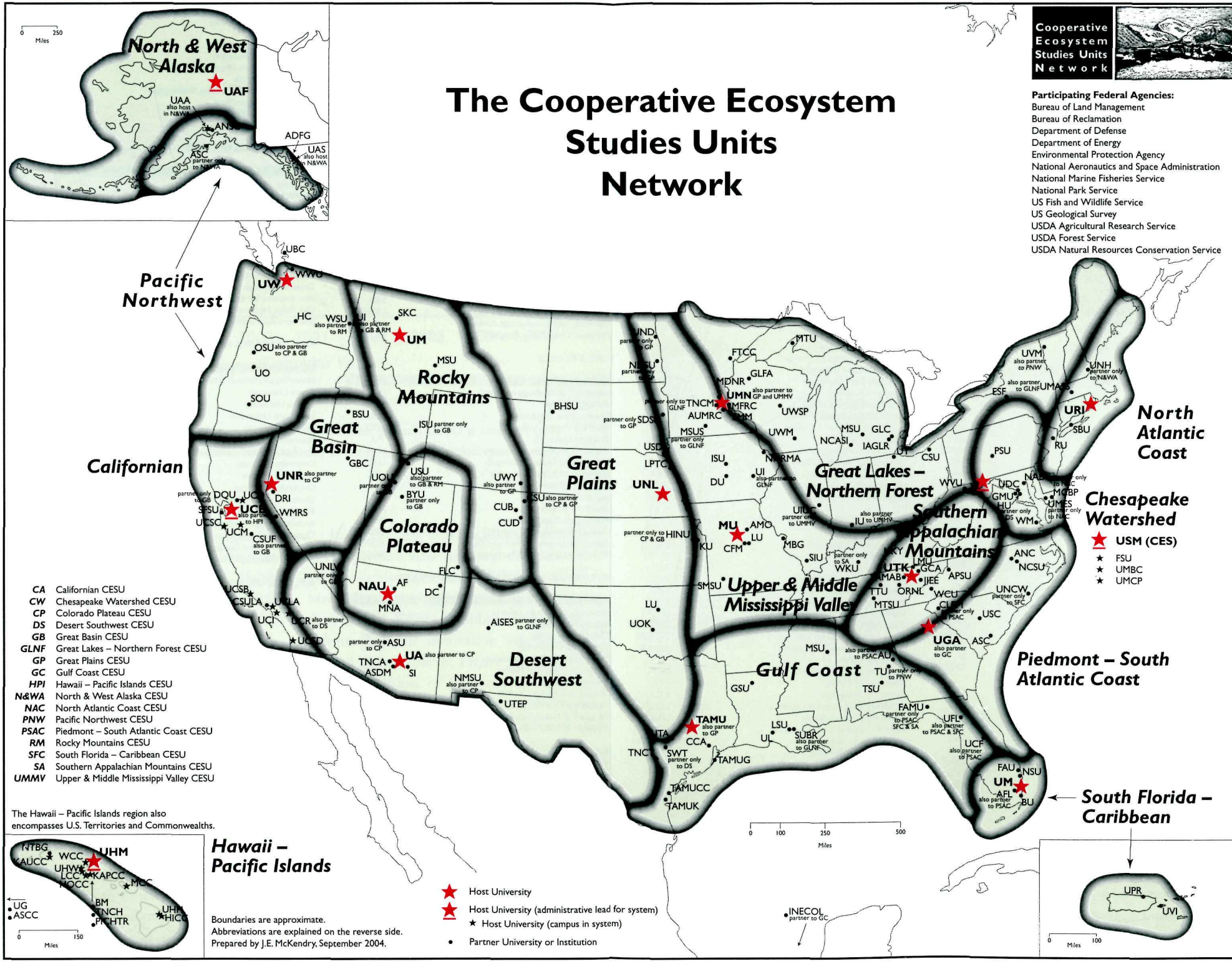
Trialability

- network established over five-year period, with early pilot efforts
- control over project funds and personnel maintained by agencies

Observability

- agreements, other information available on CESU websites
- Biennial Network Meetings share best practices

Figure 5. Selected characteristics of CESUs as innovations.


The Cooperative Ecosystem Studies Units Network
Cooperative Ecosystem Studies Units Network
Participating Federal Agencies:
Bureau of Land Management
Bureau of Reclamation
Department of Defense
Department of Energy
Environmental Protection Agency
National Aeronautics and Space Administration
National Marine Fisheries Service
National Park Service
US Fish and Wildlife Service
US Geological Survey
USDA Agricultural Research Service
USDA Forest Service
USDA Natural Resources Conservation Service
North & West Alaska
Pacific Northwest
Californian
Great Basin
Rocky Mountains
Colorado Plateau
Great Plains
Great Lakes – Northern Forest
North Atlantic Coast
Chesapeake Watershed
Southern Appalachian Mountains
Upper & Middle Mississippi Valley
Desert Southwest
Gulf Coast
Piedmont – South Atlantic Coast
South Florida – Caribbean
Hawaii – Pacific Islands
USM (CES)
FSU
UMBC
UMCP
CA Californian CESU
CW Chesapeake Watershed CESU
CP Colorado Plateau CESU
DS Desert Southwest CESU
GB Great Basin CESU
GLNF Great Lakes – Northern Forest CESU
GP Great Plains CESU
GC Gulf Coast CESU
HPI Hawaii – Pacific Islands CESU
N&WA North & West Alaska CESU
NAC North Atlantic Coast CESU
PNW Pacific Northwest CESU
PSAC Piedmont – South Atlantic Coast CESU
RM Rocky Mountains CESU
SFC South Florida – Caribbean CESU
SA Southern Appalachian Mountains CESU
UMMV Upper & Middle Mississippi Valley CESU
The Hawaii – Pacific Islands region also encompasses U.S. Territories and Commonwealths.
Boundaries are approximate.
Abbreviations are explained on the reverse side.
Prepared by J.E. McKendry, September 2004.
Host University
Host University (administrative lead for system)
Host University (campus in system)
Partner University or Institution
Miles

The CESU Network, September 2004

www.cesu.org/cesu

Californian CESU	CA
University of California (Host)	
University of California, Berkeley	UCB
University of California, Davis	UCD
University of California, Irvine	UCI
University of California, Los Angeles	UCLA
University of California, Merced	UCM
University of California, Riverside	UCR
University of California, San Diego	UCSD
University of California, Santa Barbara	UCSB
University of California, Santa Cruz	UCSC
California State University, Fresno	CSUF
California State University, Los Angeles	CSULA
San Francisco State University	SFSU

BLM, USBR, USGS, NPS, USDA FS, NRCS, NASA

Chesapeake Watershed CESU	CW
The University System of Maryland (Host)	
Center for Environmental Science	CES
Frostburg State University	FSU
University of Maryland, Baltimore County	UMBC
University of Maryland, College Park	UMCP
College of William and Mary	WM
George Mason University	GMU
Pennsylvania State University	PSU
University of the District of Columbia	UDC
National Aquarium in Baltimore	NAB

BLM, USGS, NPS, USDA FS, NRCS, DOD

Colorado Plateau CESU	CP
Northern Arizona University (Host)	NAU
Arizona State University	ASU
Colorado State University	CSU
Diné College	DC
Fort Lewis College	FLC
Haskell Indian Nations University	HINU
New Mexico State University	NMSU
Oregon State University	OSU
University of Arizona	UA
University of Nevada	UNR
Utah State University	USU
The Arboretum at Flagstaff	AF
Museum of Northern Arizona	MNA

BLM, USBR, USGS, NPS, USDA FS, NRCS

Desert Southwest CESU	DS
University of Arizona (Host)	UA
Howard University	HU
New Mexico State University	NMSU
Southwest Texas State University	SWT
University of California, Riverside	UCR
University of Texas, El Paso	UTEP
Arizona–Sonora Desert Museum	ASDM
Sonoran Institute	SI
The Nature Conservancy	TNCA

BLM, USGS, NPS, USDA FS, NRCS, DOD

Great Basin CESU	GB
University of Nevada (Host)	UNR
Boise State University	BSU
Brigham Young University	BYU
California State University, Fresno	CSUF
D-Q University	DQU
Desert Research Institute	DRI
Great Basin College	GBC
Haskell Indian Nations University	HINU
Idaho State University	ISU
Oregon State University	OSU
University of Idaho	UI
University of Nevada, Las Vegas	UNLV
University of Utah	UOU
Utah State University	USU
White Mountain Research Station	WMRS

BLM, USGS, NPS, USDA FS, ARS, NRCS

Great Lakes – Northern Forest CESU	GLNF
University of Minnesota (Host)	UMN
Cleveland State University	CSU
Fond du Lac Tribal and Community College	FTCC
Indiana University	IU
Michigan State University	MSU
Michigan Technological University	MTU
Minnesota State University, Mankato	MSUS
Southern University and A&M College	SUBR
SUNY College of Environmental Science and Forestry	ESF
University of Iowa	UI
University of Massachusetts, Amherst	UMASS
University of Toledo	UT
University of Vermont	UVM
University of Wisconsin, Madison	UWM
University of Wisconsin, Stevens Point	UWSP
West Virginia University	WVU
American Indian Science and Engineering Society	AISES
Great Lakes Commission	GLC
The Great Lakes Forest Alliance	GLFA
International Association for Great Lakes Research	IAGLR
Minnesota Department of Natural Resources	MDNR
Minnesota Forest Resources Council	MFRC
National Council for Air and Stream Improvement	NCASI
The Nature Conservancy	TNCM
The Science Museum of Minnesota	SMM

BLM, USGS, NPS, USDA FS, NRCS, NASA

Great Plains CESU	GP
University of Nebraska (Host)	UNL
Black Hills State University	BHSU
Colorado State University	CSU
Langston University	LU
Little Priest Tribal College	LPTC
North Dakota State University	NDSU
South Dakota State University	SDSU
Texas A&M University	TAMU
University of Minnesota	UMN
University of North Dakota	UND
University of Oklahoma	UOK
University of South Dakota	USD
University of Wyoming	UWY

BLM, USBR, USGS, NPS, USDA FS, NRCS

Gulf Coast CESU	GC
Texas A&M University (Host)	TAMU
Auburn University	AU
Grambling State University	GSU
Louisiana State University	LSU
Mississippi State University	MSU
Southern University and A&M College	SUBR
Texas A&M University, Corpus Christi	TAMUCC
Texas A&M University, Galveston	TAMUG
Texas A&M University, Kingsville	TAMUK
Troy State University	TSU
University of Central Florida	UCF
University of Florida	UFL
University of Georgia	UGA
University of Lousiana at Lafayette	UL
University of Texas, Austin	UTA
Coastal Conservation Association	CCA
Instituto de Ecología, A.C.	INECOL
The Nature Conservancy	TNCT

BLM, USGS, NPS, USDA FS, NRCS, DOD, NASA

Hawaii – Pacific Islands CESU	HPI
University of Hawaii (Host)	
University of Hawaii, Manoa	UHM
University of Hawaii, Hilo	UHH
University of Hawaii, West Oahu	UHW
Hawaii Community College	HICC
Honolulu Community College	HOCC
Kapiolani Community College	KAPCC
Kauai Community College	KAUCC
Leeward Community College	LCC
Maui Community College	MCC
Windward Community College	WCC

Hawaii – Pacific Islands CESU (cont.)	HPI
University of California, Berkeley	UCB
University of Guam	UG
American Samoa Community College	ASCC
Bishop Museum	BM
National Tropical Botanical Garden	NTBG
The Nature Conservancy	TNCH
Pacific International Center for High Technology Research	PICHTR

BLM, USFWS, USGS, NPS, USDA FS, NRCS, DOD

North & West Alaska CESU	N&WA
University of Alaska (Host)	
University of Alaska, Anchorage	UAA
University of Alaska, Fairbanks	UAF
University of Alaska, Southeast	UAS
University of New Hampshire	UNH
Alaska SeaLife Center	ASC

BLM, USGS, NPS, USDA FS, NRCS

North Atlantic Coast CESU	NAC
University of Rhode Island (Host)	URI
Rutgers University	RU
Stony Brook University	SBU
University of Maryland, Eastern Shore	UMES
University of Massachusetts, Amherst	UMASS
Maryland Coastal Bays Program	MCBP

USGS, NPS, NRCS

Pacific Northwest CESU	PNW
University of Washington (Host)	UW
Heritage College	HC
Oregon State University	OSU
Southern Oregon University	SOU
Tuskegee University	TU
University of Alaska, Anchorage	UAA
University of Alaska, Southeast	UAS
University of British Columbia	UBC
University of Idaho	UI
University of Oregon	UO
University of Vermont	UVM
Washington State University	WSU
Western Washington University	WWU
Alaska Department of Fish and Game	ADFG
Alaska Native Science Commission	ANSC

BLM, USBR, USFWS, USGS, NPS, USDA FS, NRCS, EPA

Piedmont – South Atlantic Coast CESU	PSAC
University of Georgia (Host)	UGA
Auburn University	AU
Clemson University	CLEM
Florida A&M University	FAMU
North Carolina State University	NCSU
University of Central Florida	UCF
University of Florida	UFL
University of South Carolina	USC
Audubon of Florida	AFL
Audubon of North Carolina	ANC
Audubon of South Carolina	ASC

BLM, USFWS, USGS, NPS, USDA FS, ARS, NRCS

Rocky Mountains CESU	RM
University of Montana (Host)	UM
Colorado State University	CSU
Montana State University	MSU
Salish Kootenai College	SKC
University of Colorado at Boulder	CUB
University of Colorado Health Sciences Center	CUD
University of Idaho	UI
University of Wyoming	UWY
Utah State University	USU
Washington State University	WSU

BLM, USBR, USGS, NPS, USDA FS, NRCS

South Florida – Caribbean CESU	SFC
University of Miami (Host)	UM
Barry University	BU
Florida A&M University	FAMU
Florida Atlantic University	FAU
Nova Southeastern University	NSU
University of Florida	UFL
University of North Carolina, Wilmington	UNCW
University of Puerto Rico	UPR
University of the Virgin Islands	UVI
Audubon of Florida	AFL

BLM, USFWS, USGS, NPS, NRCS

Southern Appalachian Mountains CESU	SA
University of Tennessee (Host)	UTK
Appalachian State University	APSU
Florida A&M University	FAMU
Lincoln Memorial University	LMU
Middle Tennessee State University	MTSU
Tennessee Technological University	TTU
University of Kentucky	UKY
Western Carolina University	WCU
Western Kentucky University	WKU
Great Smoky Mountains Conservation Association	GCA
Joint Institute for Energy and the Environment	JIEE
Oak Ridge National Laboratory	ORNL
Southern Appalachian Man and Biosphere	SAMAB

BLM, USFWS, USGS, NPS, USDA FS, NRCS, DOE

Upper & Middle Mississippi Valley CESU	UMMV
University of Missouri (Host)	MU
Drake University	DU
Indiana University	IU
Iowa State University	ISU
Lincoln University	LU
Southern Illinois University	SIU
Southwest Missouri State University	SMSU
University of Illinois	UIUC
University of Iowa	UI
University of Kansas	KU
University of Minnesota	UMN
Audubon of Missouri	AMO
Audubon Upper Mississippi River Campaign	AUMRC
Conservation Federation of Missouri	CFM
Missouri Botanical Garden	MBG
National Mississippi River Museum and Aquarium	NMRMA

BLM, USGS, NPS, NRCS, DOD

Participating Federal Agencies:	
Bureau of Land Management	BLM
Bureau of Reclamation	USBR
Department of Defense	DOD
Department of Energy	DOE
Environmental Protection Agency	EPA
National Aeronautics and Space Administration	NASA
National Marine Fisheries Service	NMFS
National Park Service	NPS
US Fish and Wildlife Service	USFWS
US Geological Survey	USGS
USDA Agricultural Research Service	ARS
USDA Forest Service	USDA FS
USDA Natural Resources Conservation Service	NRCS

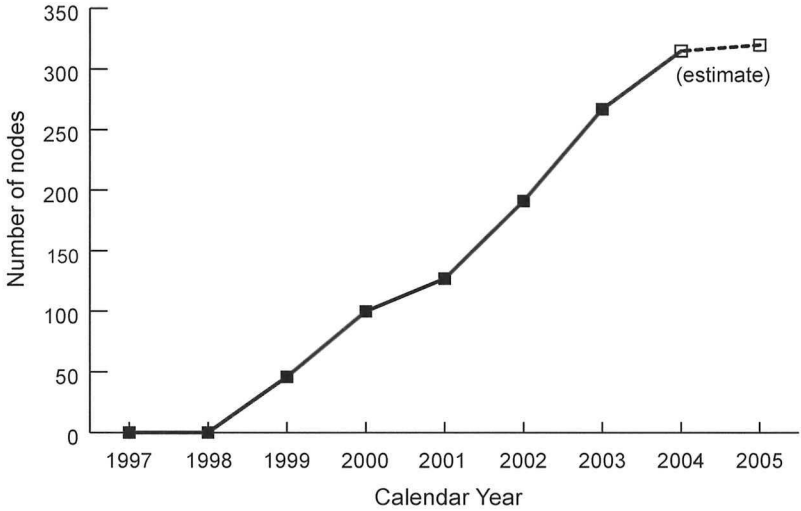


Figure 6. Growth curve of CESU Network. Each organization in each CESU is counted as a node and linkage; hence the cumulative total includes organizations participating in more than one CESU as multiple nodes.

the National Parks Omnibus Management Act of 1998 was nearing completion in Congress. It included language clarifying the NPS mandate for research (Sec. 202) and specific authority to enter into the CESU cooperative agreements along with other federal agencies (Sec. 203). The act passed in November 1998. By early 1999, the first elements of the CESU Network were ready for establishment. In June 1999, a founding meeting was held in Washington, D.C., to establish both the Network and the first pilot CESUs. A memorandum of understanding between the federal agencies (at that time the USGS, NPS, USBR, BLM, USDA FS, and Department of Energy (DOE) was signed, establishing the CESU Council to oversee Network policy and leadership. The four pilot CESUs were also established.

In succeeding years, additional rounds of competition were held and the Network grew steadily (four new CESUs in 2000, two in 2001, two in 2002, four in 2003, and then a final CESU established in 2004). Adoption of the innovation followed the general growth curve; Figure 6 shows the annual addition of partners to existing CESUs ("nodes" in network terminology) as a cumulative growth curve. Additional federal agencies joined the CESU Network: the EPA, Department of Defense (DOD), and USFWS in 2000, National Aeronautics and Space Administration (NASA) in 2001, Natural Resources Conservation Service (NRCS) and Agricultural Research Service (ARS) in 2002, and National Marine Fisheries Service (NMFS) in 2003. Biennial national meetings were held in 2001 and 2003, bringing together the rep-

resentatives of the federal agencies, universities, and other partners to the Network. A CESU Network website (www.cesu.org/cesu) was established, and individual CESUs formed their managers committees, prepared strategic plans, and established websites and operating procedures.

Most importantly, the individual CESUs began to conduct research, technical assistance, and education projects—the purpose for which the Network was established. Projects varied by type (research, technical assistance, education, or a combination thereof), agency sponsor, size (measured in funding level), and discipline (natural, physical, social and cultural sciences). By 2002, a "First Inventory" of projects was available, covering the calendar years 1999–2001 (CESU Network 2003a). In those first few years, over 500 projects were completed or underway. Examples included:

- Understanding the effects of river otter reintroduction on muskrat and mussel populations at Mammoth Cave National Park, a combined NPS/USGS project of the Southern Appalachian Mountains CESU;
- Developing a methodology for preparing Voyageurs National Park's visitor experience and resource protection plan, a project of the Great Plains CESU;
- Assessing the relative distribution, abundance, and demographic structure of the American alligator in relation to habitat, water levels, and salinities, a combined NPS/USGS/USFWS project in the South Florida–Caribbean CESU; and
- Describing traditional uses of Aniakchak National Monument and Preserve, a project of the Pacific Northwest CESU.

As the CESU Network grew—in participating federal agencies, university and other partners, and in projects completed and underway—the federal government and universities gained experience in developing administrative procedures, common vocabularies, and organizational structures and mechanisms to support the CESU mission. The Network moved closer to completion. By July 2004, all seventeen of the proposed CESUs had been established, providing full national coverage. Simultaneously, the Network began a process of maturation.

Maturation

In network science, maturation of networks occurs when critical missing nodes are added and some nodes are dropped, new functional links are established or improved, and new clusters are formed. For the CESU Network, this maturation process is well underway. By fall 2004, each of the 17 CESUs will have added new partners (or have additions underway); the current number of nonfederal partners is 181. Six partners have withdrawn (one because it ceased to exist; others as they found participation was not in their interest). As new nonfederal partners join, the expertise available through each CESU is broadened. As additional federal agencies join, agency coordination is enhanced and opportunities for collaborative projects increase.

Several CESUs have begun joint meetings and sharing functions with each other —the linking of clusters identified as a phase transition in network science. For example, the Rocky Mountains, Great Basin, and Colorado Plateau CESUs held a joint managers meeting in February 2004 at Utah State University, which is a partner ("node" in network terms) in all three of these CESUs. At the meeting, examples of projects in progress through each of these

agreements were presented. There was also an in-depth discussion of the educational needs of the federal agencies and how the academic partners can help fill those needs.

Multi-agency, multi-partner, and multi-CESU projects are beginning to emerge. For example the Desert Southwest CESU has developed the concept of "banner project"—a single project that involves *all* CESU partners. The Chesapeake Watershed CESU and Southern Appalachian Mountains CESU, in collaboration with The Pennsylvania State University, hosted a workshop on "Restoration of American Chestnuts within National Parks" in Asheville, North Carolina, in May 2004. Participants were from the NPS, USDA FS, USFWS, American Chestnut Foundation, several state agencies, and approximately 15 universities. Another example of a multi-CESU project was the production of a video broadcast by the Discovery Channel in May 2004 called "The Desert Speaks: Monumental Dunes." The project described in the broadcast involved both the Desert Southwest and Rocky Mountains CESUs.

Program managers and contracting officials from the federal agencies and universities have gained experience and applied their skills to building the CESU Network. For example, after the Colorado Plateau CESU was established, BLM hosted two workshops to design effective administrative protocols for developing, initiating, and tracking task orders and modifications to the CESU agreement. The CESUs that were created early in the development of the Network have advised more recently established CESUs on matters related to organizational structure, strategic planning, project protocols and management, and other tasks.

Agencies have made progress in staffing CESUs. As described earlier, federal agencies can contribute scientific and/or professional staff to support and promote agency participation in CESUs. In some cases, these federal personnel are located and working at CESU host universities. Federal personnel are supervised and supported by their respective agencies through existing administrative systems. For example, NPS, as part of its Natural Resource Challenge, has funded an NPS coordinator for 12 of the 17 CESUs. For the remaining five CESUs, coordinator positions are currently being supported through other funding sources, or existing coordinators cover responsibilities at a second CESU. In addition, several NPS regional offices are now supporting cultural resource specialist staff positions, also duty-stationed at CESU host universities, to help meet the multidisciplinary needs of the NPS. BLM has also begun to place coordinators at CESUs in regions where the agency has significant management responsibilities. For example, BLM has a coordinator assigned to the Great Basin CESU, located at the University of Nevada–Reno. Other agencies, such as USDA FS and USGS, already have personnel based at universities in the CESU Network who assist their agency's participation in CESUs.

Maturation also requires review and renewal. Each CESU agreement has a five-year term, subject to renewal. The renewal process for each CESU includes an important and formal review of CESU activities over the previous five years, following steps and criteria approved by the CESU Council. The review has three key parts: (1) a self-assessment prepared by the host university, working with its other nonfederal partner institutions; (2) a review and recommendation by the CESU's managers committee; and (3) an independent review prepared by up to three external reviewers identified by the CESU's managers com-

mittee. The reviews also provide an opportunity for all partners to consider improvements to the CESU.

The Council uses the information from each review to decide on whether to renew a CESU. If the decision is favorable, a renewed agreement is prepared that continues the existing agreement for the operation and maintenance of the CESU. The first four CESUs (established in 1999) were renewed in spring 2004, with renewed agreements now in effect for another five years (until 2009). These were the Colorado Plateau, North Atlantic Coast, Rocky Mountains, and Southern Appalachian Mountains CESUs.

The reviews reveal the scale and scope of individual CESUs. The Rocky Mountains CESU is an example. During its start-up period of FY1999–2004, the Rocky Mountains CESU facilitated 299 research, technical assistance, and education projects, with funding of just over $16.2 million. Of the total number, 164 (55%) were research, 113 (38%) were technical assistance, and 22 (7%) were education projects. The University of Montana (the host university) was engaged in 40% of these projects; the other partners in 60%, and all partners were involved in at least some CESU projects. All of the Rocky Mountains CESU federal agency partners were active in projects; the most active agencies were BLM, USDA FS, and NPS. Figure 7 shows the total project funding by federal agency.

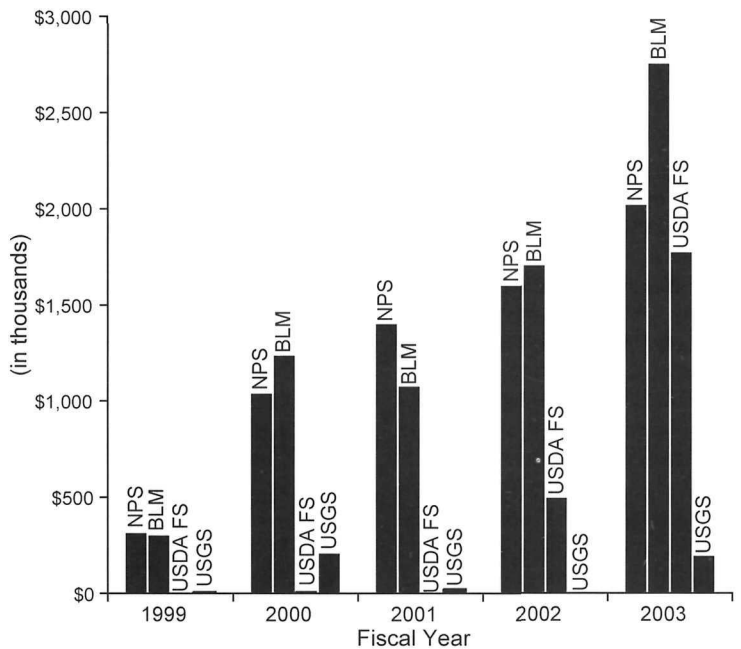


Figure 7. Rocky Mountains CESU project funding, by agency, FY99–03 (source: Rocky Mountains CESU Self-Assessment Report, University of Montana, 2004).

The other three CESUs with completed five-year reviews also reported information about projects and participation. The scope and scale of participation varied as a function of the number of federal partners, geographic extent of the CESU region, and involvement in national-level collaborative projects with the federal agencies. The review and renewal process for the four CESUs established in 2000 (the Desert Southwest, Great Plains, Pacific Northwest, and South Florida–Caribbean CESUs), will begin in fall 2004.

Maturation also includes adapting to new conditions. One key example is the CESU Council's recent decision to increase the overhead rate for CESU projects across the Network from 15% to 17.5%, effective 1 May 2004. This increase reflects the general percentage increase in the cognizant overhead rate accepted by federal agencies based on detailed surveys by the Office of Management and Budget and the Office of Naval Research. At some CESUs, administrators at the host institution have agreed to use this 2.5% increase in overhead costs to help support the coordination and administration of the CESU. The 2.5% increase adapts to the economic challenges facing the nation's universities, and maintains the low overhead rate that is a core commitment (and substantial contribution) of the Network's nonfederal partners.

There are other, more subtle (although no less important) examples of adaptations underway. A large number of practical (and tractable) problems related to projects, equipment, reports, student assistants, and budgets are being solved locally, and with local options—the preferred choice in such a decentralized network. CESUs are largely self-organizing, creating new linkages, new clusters, and expanding the capability and capacity of the Network—and adaptation occurs most effectively at the local level.

Maturation includes creating a long-term strategy for the CESU Network. In 2003, the *CESU Network Strategic Plan* for 2004–2008 (CESU Network 2003b) was published after considerable work by the Council, input from the agencies, and a public comment period. This strategic plan describes the CESU mission and strategic goals for the Network. To achieve these strategic goals, specific activities and actions are proposed, including three key Network initiatives. The initiatives focus on (1) making existing information available and useful, (2) encouraging agency collaboration and coordination, and (3) creating professional development opportunities for federal resource managers and university faculty. The first step in implementing these initiatives is to secure support through a mix of federal and nonfederal funding sources.

Maturation also means increased awareness by the media, Congress, and interest groups. CESUs have been reported on in the local, regional, and national press (see for example, DeWeerdt 2002). Briefings of congressional staff have occurred, and there is increased awareness in Congress as to the potential and value of CESUs. Several organizations (an example is the National Association of State Universities and Land-Grant Colleges) have made their views known to the administration and Congress. All of these efforts are part of the adoption and diffusion of the CESU Network, and signal its maturation as an organization and network.

Trajectory: Future Challenges of the CESU Network

While growth and maturation may characterize the CESU Network currently, what does its near-term future hold? The Network's trajectory presents several col-

laborative challenges. Five seem most central.

The first challenge is funding—providing the resources needed for CESUs to reach their full potential. At the individual CESU level, such funding is perhaps best (and most likely) when provided through a diversity of sources. These include adequate administrative support, overhead consistent with cooperative ventures such as CESUs, and sound project budgeting that ensures each and every project pays all of the direct and allowable costs associated with that project. At the Network level, funding of the CESU Council's initiatives (particularly the information initiative that provides infrastructure support to individual CESUs) would make the Network more responsive and expand awareness of, access to, and availability of CESU project results. Rather than costs, these expenditures are reasoned investments—adding value and reducing overall government expenditures by helping the Network to "work smarter" and take advantage of its "small-world" network architecture.

The second challenge is accountability. Making sure that the activities, expertise, projects, and (most importantly) outcomes of CESUs are accounted for is essential in the current and foreseeable management and political climate. Accountability is best monitored by the individual agencies and universities, rather than creating a central CESU office oversight function. Performance measures may vary by agency, kind of project, and level of funding. Yet some "roll-up" capability is useful, and the challenge is to balance the need for information about CESU activities and expertise with the very real cost of assembling such information. Again, the relatively few degrees of separation amongst the nodes make information-sharing within the Network plausible and practical.

The third challenge is quality—the need for sound science and scholarship, for timely delivery of completed efforts, and for the consistent delivery of usable knowledge. Quality in science has, of course, multiple dimensions. Basic research may be measured by publication in scientific journals; technical assistance, in the success of management actions based on provided advice and counsel. By linking federal agencies to university investigators, CESUs combine the science cultures of academe (with its "publish or perish" peer review, and tenure and promotion standards) and that of the federal scientific community. How CESUs—as well as other federally supported science programs—respond to the challenge of quality will be essential to their future.

The fourth challenge is inclusion. CESUs were conceived as "virtual" organizations that bring together the expertise of universities, other organizations, and the federal government, and focus that expertise on solving problems for federal resource, environmental, and research agencies. Such networks are successful to the extent that most nodes are active. The CESU Network needs to continually ensure that federal agencies, host universities, and partner institutions all participate—through individual projects and in the general activities of each CESU. In particular, the commitment to engage minority institutions needs to be continually reinforced, and the minority institutions encouraged (through inclusion in funded projects) to be "at the CESU table" as full and enthused participants.

The fifth challenge is the challenge of bureaucracy. Policies, rules, regulations, and guidelines all have their place and purpose. They are based on statutory requirements and help to ensure common understanding and fairness. But when the

demands of bureaucracy overtake government's ability to conduct public service, and the struggle for agency "turf" discourages (or prevents) collaborative effort, then a balance between administrative "gatekeeping" and good sense must be reachieved. Like other maturing organizations (particularly in the business sector), the CESU Network will need to continually strive to remain lean, responsive, innovative, and willing to experiment. It must remain a "learning organization"—and adopt new best practices as they develop. To accomplish this, the technical representatives and other officials of participating agencies and universities need to work together and be supported by agency leadership in their efforts. The CESU Council's philosophy of maximizing local option will need to be continually reinforced.

Conclusion

There are other challenges, of course. But the future trajectory of CESUs will also include some important successes. The recent completion of the Network, and its national coverage from the Caribbean to the Pacific Ocean, will lead to an increasing awareness of CESUs. The renewal of the first-round CESUs has shown the viability of the pilot efforts, and the value of a rigorous evaluation process. Federal agencies such as NRCS and ARS—with traditional emphases on intramural research—are finding the CESU Network a valued complement to their existing programs, and joining several (in the case of NRCS, all) CESUs. Nonfederal partners will be added to existing CESUs. New and innovative uses for the CESU Network will be discovered by federal agencies, universities, and other partners to better support their objectives and improve collaboration. The issues of funding, accountability, quality, inclusion, and bureaucracy will be imaginatively managed for public benefit.

The state of the CESU Network is, in network science terms, that of a robust, decentralized network undergoing an important phase transition. Literally hundreds of individuals have been involved—faculty and students at universities; federal resource managers in the nation's parks, refuges, forests, and rangelands; contracting officials and university administrators; the CESU Council; agency leaders; and others. All deserve credit for their hard work and creative actions to build this emergent and important network.

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