Our nation’s watersheds are at risk

The Research Drivers:

Drought

- Non-point source pollutants
- Micro-pollutants
- Biodiversity
- Sustainability

Economy

Ecology
Water quantity and quality will determine economic vitality and future patterns of economic growth.

Is it time to shift the water resources management paradigm to the digital watershed and intelligent river?

Slide courtesy of Gene Eidson
• **real-time data** will be necessary to optimize water withdrawal, wasteload allocation, and hydropower generation while preserving the ecology of our rivers and streams.

• **remote data acquisition system** will be essential to establish long-term water quality trends, monitor flow, track land-use changes, document pollution impacts, and effectively manage major rivers.
“Policymakers need to figure out how to supply water without degrading the natural ecosystems that provide it.”
The Intelligent River™ Project

Building on Clemson CLUE Project

“Changing Land Use and the Environment”
Cyberinfrastructure Components

- QA/QC
- Analyze
- Visualize
- Archive

Source: WATERS Network cyberinfrastructure, NSF
We’re not the first sensor network...

In situ data acquisition projects span the globe

- Resource management
- Precision agriculture
- Volcano monitoring
- Invasive species detection
- Wildfire tracking
- Threat detection
- Smart structures
- Habitat monitoring

The common goal:
Dense instrumentation of the physical world to support management, discovery, and protection

Photos retrieved from public websites; they are assumed to be in the public domain
More Information Tomorrow:

Clemson University Center for Watershed Excellence

Gene Eidson

Session 1 Watershed Management – 10:15-11:45
3 Demonstration Projects

- Bannockburn
- Savannah River
- Lake Issaqueena and Honeycutt Creek
Enhancing Traditional Research Methods: Installing Sensor Networks
Bannockburn Plantation Development Plan
Bannockburn Sensor Network

Sensor Type
- Existing well
- Flow Measurement
- Piezometer
- SM
- Tipping-Bucket
- Well-rain
- Bannockburn Plantation
- Intensive Study Watershed
Hydrologic and Water Quality Monitoring

Weather Station Array, including Rainfall and Solar Radiation

Culvert Surface Water Levels and Flows

Stream Water Quality

Water Table Levels, Subcanopy Rain, and Piezometric Head

Surface Water Sampling
Creating Digital Coastal Watersheds: the Remote Data Acquisition Network at Bannockburn Plantation

- Daniel R. Hitchcock
- William H. Conner
- Samuel Esswein
- Christopher Post
- Thomas M. Williams
- Elena Mikhailova
- Anand D. Jayakaran
- Rob Baldwin
- Bo Song

Session 2 CI 2 - 1:30-3:00
Physical Installation/Enclosure

- Solar Panels, Gel-Cell Battery
- Resistance to weather and bugs
- Minimum of Materials
Clemson Forest Sensor Network

- Deep woods – impedes wireless communication range
- Lack of cellular coverage
- Hilly terrains – absolute blockage, often over long distances
- Recurring cost and limited bandwidth of cellular/satellite service

Wireless networking objectives
- A methodology that
  - provides adequate and reliable bandwidth
  - scales to a large area physically and economically
Explore Higher Bandwidth/Lower Cost

- Wi-Fi mesh network: IEEE 802.11b/g
- Zigbee sensor network: IEEE 802.15.4

- Clemson Forest
  - Long range Wi-Fi (**fixed direction**): IEEE 802.11a & b/g

- Hunnicut Creek
  - Long range Wi-Fi (**steerable direction**): IEEE 802.11b/g
More Information Later Today:

Enabling Broadband Data Access for the Digital Watershed with Heterogeneous Wireless Networks

• Gayatri Venkatesh
• Kuang-Ching Wang
• Christopher Post
Web-Based Data Access and Visualization
• State of the art facility

• Secure & controlled environment.

• Continuously monitored by Network Operations Center

• Automated Data Backups & System Recovery
MonitorGWT

- Java
- NaradaBrokering – Community Grids Lab, Indiana University
- NetCDF/Common Data Model – Unidata/UCAR
- THREDDS Data Server – Unidata/UCAR
- Xenia/PostgreSQL – SEECOOS DMCC
- Mina – Apache Software Foundation
Application of Publish/Subscribe Messaging for Management of Streaming Water Resource Data

- Sam Esswein
Web-Based Data Access and Visualization
Available sensors
Mouseover sensor links to view color legends.

Federal Providers

- **gage_height**
- **ground_water_level**
- **headwater_elevation**
- **reservoir_water_level**
- **streamflow**
- **tailwater_elevation**

Visible platforms
Click on a platform link to locate it on the map.
Platforms that have not already been selected are added to the bottom of the list.

- usgs_02109500
- usgs_02110400
- usgs_02110500
- usgs_02110701
- usgs_02110704
- usgs_02110725
- usgs_02110729
- usgs_02110760
- usgs_02110777
- usgs_02110800

armycorp_hartwell
Aug 26 07:00 EDT
Parameter Latest reading Graph?
headwater_elevation 645.59 ft
tailwater_elevation 474.74 ft
Show all parameters on one graph?
Google Earth Drill Down

Search
- Fly To
- Find Businesses
- Directions

Fly to e.g., New York, NY

Places
- My Places
  - Sightseeing
    - Select this folder and click on the 'Play' button below, to start
      - v_xenla_top_obs.kml
      - Temporary Places

Layers
- Primary Database
- Geographic Web
- Roads
- 3D Buildings
- Street View
- Street View
- Borders and Labels
- Traffic
- Weather
- Gallery
- Global Awareness
- Places of Interest
- More
- Terrain

Context sensitive

Google Earth Drill Down

Slide courtesy of David L. White

SCWRC 10/2008
System management and performance

Long-term archival

Reuse across federated systems

Increase data life cycle

QA/QC
• QAQC Level 0-3
  • Level 0 no checks
  • Level 1 duplicate, range and step check with associated flagging levels
  • Level 2

Slide courtesy of David L. White
Demonstration of Intelligent River Science Gateway

- David L. White
- Conference Exhibit Area

http://www.intelligentriver.org
Modeling Watersheds

The variables measured at open weather stations:
- Humidity
- Temperature
- Rainfall
- Radiation
- Barometer pressure
- Wind speed/direction

Sap flow, dendrometer bands – plots located with water table and soil moisture sensors

Water table wells with soil moisture sensors between A and E horizons plus sub-canopy rainfall measurements

The red dots show piezometric potential measurement depths at multi-level piezometers
Visualization of longleaf forest using computer technique:

One obvious advantage is:

We can grow trees on computer with different composition, tree sizes, and densities, in several hours, instead of have to wait 50 years in the field, thus we can do all sorts of experiment on computer.
Large Scale Visualization

Objectives:
- Transformative public outreach
- Photorealistic, realtime scenes
- Past, present, and prospective views
- Integrated hydrological, ecological, and land-use models

"It's a Small World: Enhancing Human Cognition through Virtual Dioramas"
- Geist, Hallstrom, Hitchcock, Song

[NSF CDI proposal pending]

Photos retrieved from public websites; they are assumed to be in the public domain

- Forest images by Geist and Steele
More Information Later Today:

It’s a Small World: Enhancing Human Cognition through Virtual Dioramas

• Jason Hallstrom
Acknowledgments

- Principal Investigator: Dr. Gene Eidson, Director Restoration Ecology Center; Director Clemson-Baruch (Program Manager)

- Co-PIs:
  - Dr. William Conner, Forested Wetland Ecologist, (Clemson-Baruch)
  - Dr. Chris Post, Forestry and Natural Resources, Clemson (Technical Lead)
  - Dr. Oscar Filte, Savannah River
  - Dr. Jill Gemmill, Clemson Computing & Information Tech. (Program Manager)
  - Dr. John Hayes, Agriculture & Biological Engineering (CLUE)
  - Dr. Jason Hallstrom, School of Computing (Sensors and Sensor Networks)
  - Dr. Dan Hitchcock, (Clemson-Baruch)
  - Tim Howard, Clemson Computing & Information Tech. (Project Manager)
  - Dr. Steve Klaine, Biological Sciences (CLUE)
  - Dr. Charles Privette, Agriculture and Biological Engineering (CLUE)
  - Calvin Sawyer, Applied Ecology, (Center Coordinator)
  - Dr. Kuang-Ching Wang, Electrical & Computer Eng. (Wireless Networking)
  - Dr. David L. White, Clemson Computing & Information Tech. (Technical Lead)
Acknowledgments (Cont’d)

- Fahra Ali, CCIT
- Dr. Devendra Amatya, USDA Forest Service
- Rahul Amin, ECE Grad Student
- Dr. Rob Baldwin, Forestry
- Chris Behrens, CCIT
- Stan Birchfield
- Dr. Richard Brooks, ECE
- Dr. Tim Callahan, College of Charleston
- Shari Carter, SC Governor’s School
- Rebecca Crane, Grad Student
- Knight Cox, Clemson Forest Manager
- Andy Dalton, SoC Grad Student
- Brian Daugherty, CCIT
- Jamie Duberstein, Grad Student
- Ed Duffy, CCIT
- Sam Esswein, CU Forestry Grad Student
- Chase Finch, CCIT
- Mike Fry, ECE Grad Student
- Charleton Galvarino, Consultant
- Dr. Robert Geist, School of Computing
- Ben Graham, CU Student
- Dr. Sebastien Goasguen, SoComputing
- Jason Isenhower, SC Governor’s School
- Dr. Anand Jayakaran, Clemson-Baruch
- Brian Jones
- Shawn Kelly
- Wil Kirwan, SoC student and CCIT
- Dr. Ken Krauss, USGS Lafayette, LA
- Josh Lawrence
- Sandeep Lokala, ECE Grad Student
- Mike McLeod
- Dr. Elena Mikhailova, Forestry
- Dr. Shrideep Pallickara, Indiana U.
- Shashank Parab, CCIT
- Sandi Piazza, CCIT
- Jeremy Pike, Graduate Student
• Sajindra Pradhananga, ECE Grad student
• Dr. Charles Privette, CLUE
• Drake Rogers, CU Biosystems Eng. Grad Student
• Dan Schmiedt, CCIT Chief Network Engineer
• Dr. Julie Sharp, Applied Economics
• George Schwab, SoC student
• John Smink, CLUE
• Dr. Bo Song, Clemson-Baruch
• Irfan Tak, CCIT
• Andrew Thomas, Consultant
• James Vaughn, SC Gov’s School
• Gayatri Venkatesh, ECE Grad Stud.
• Jeff Vernon, Technician
• Dr. Vijay Vulava, College of Charleston
• Brian Williams, Technician
• Dr. Tom Williams, Clemson-Baruch

• Clemson-Baruch Summer interns
• Spring 2008 ECE Software Practicum Student Team