**Long-Term Data Needs for River . . . cont'd.**


Defenders of Wildlife, 1637 Laurel St., Lake Oswego, Oregon 97304, (503) 697-3222].

Karr, J.R. and E.W. Chu, 1999. Restoring Life in Running Waters; Better Biological Monitoring. Island Press, ISBN 1-55963-674-2.

Mattole Restoration Council (MRC), 1995. Dynamics of Recovery; A Plan to Enhance the Mattole Estuary. Mattole Restoration Council, Petrolia, California.

Underwood, A.J., 1996. Spatial and Temporal Problems With Monitoring. *In:* River Restoration: Selected Extracts From the Rivers Handbook, G.E. Petts and T. Calow (Editors). Blackwell Science Publ., ISBN 0-86542-919-7, pp. 182-204.

Wolfenden, J.A., 1997. The System Approach to Dealing With the Complex Issues Typically Encountered Within the Context of Integrated Catchment Management. Paper presented at 2nd Integrated Catchment Management Conference, Canberra, Australia (http://www.une.edu.au/wpr/NEEEG/ICM_paper.html).

Ziemer, R.R., 1998. Monitoring Watersheds and Streams. *In:* Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story. USDA Forest Service Gen. Tech. Report PSW-GTR-168, pp. 129-136.



AUTHOR LINK

Christine Perala, Ph.D.
PWA Associate Consultant
Phillip Williams & Associates Ltd.
322 NW 5th Ave., Ste. 234
Portland, OR 97209
(503) 226-6810 / Fax: (503) 226-6816

John L. Gardiner, Principal
PWA Principal-In-Charge
Phillip Williams & Associates Ltd.
322 NW 5th Ave., Ste. 234
Portland, OR 97209
(503) 226-6810 / Fax: (503) 226-6816

E-MAIL

perala@teleport.com
gardiner@pwa-oregon.com


**Christine Perala** is a bio-geomorphologist working on Pacific Northwest streams on issues relating to recovery of streamside and floodplain plant communities. Research for her Ph.D. (Physical Geography) focused on floodplain woody vegetation interactions with fluvial and hydraulic processes. Christine is actively involved in developing strategies for watershed and floodplain revegetation within a geomorphic context in the Pacific Northwest. She is a Switzer Fellow and lives near Portland, Oregon.

**John Gardiner** is a civil engineer and Ph.D. specializing in catchment (watershed) strategic planning for water resources, including flood defense and sustainability. He pioneered catchment managing planning for flood defense in the U.K. in the National Rivers Authority. John has authored many papers on sustainability for the water environment, best management practices for stormwater to protect the hydrologic cycle, and nature conservation within river engineering. For several years he was tenured Professor of Environmental Management in the U.K., and is now Principal of the PNW Office of Philip Williams & Associates, Portland, Oregon.

❖ ❖ ❖

# ▲ Employment Opportunity

# EXTENDING HYDROLOGIC RECORDS WITH TREE RINGS

**Connie Woodhouse**

Water resource planning is primarily based on 20th Century instrumental records of climate and streamflow. Unfortunately, long instrumental records are few and far between, and even these records capture only a limited portion of the range of natural hydrologic variability that is possible. Longer records are needed to evaluate 20th Century extreme flow events in a long-term context, and to enable the detection of low-frequency variability that may underlie short-term variations in flow.

Tree-ring reconstructions of streamflow (i.e., dendrohydrological reconstructions) can be a useful tool for augmenting existing instrumental streamflow records. Trees are natural recorders of climate variability and have proven to be useful for extending records of climate and streamflow back hundreds of years. Tree growth is related to a variety of climatic and nonclimatic factors which are integrated into patterns of annual ring widths. Tree rings can be effective proxies for streamflow, because trees in selected locations respond to a set of climate-related factors – including precipitation and evapotranspiration – that also influence streamflow variability (Meko *et al.,* 1995). Trees growing in the semi-arid western United States depend on winter precipitation to recharge soil moisture, and thus are useful for reconstructing annual streamflow (e.g., Stockton and Jacoby, 1976; Smith and Stockton, 1981; Earle, 1993; Meko and Graybill, 1995). In the eastern United States, trees are more sensitive to growing season moisture, and are more suitable for reconstructions of summer flow or low flow (e.g., Cook and Jacoby, 1983; Phipps, 1983; Cleaveland and Stahle, 1989; Cleaveland, 2000).

*Although tree-ring reconstructions of streamflow offer invaluable insights on the long-term and low-frequency behavior of streamflow, further work is needed to increase the usefulness of these records for water resource management and planning*

## GENERATING STREAMFLOW RECONSTRUCTIONS FROM TREE RINGS

The generation of useful reconstructions of streamflow relies upon sampling (usually with an increment borer) in areas where trees are sensitive to the same suite of climatic conditions that influence streamflow. Although tree growth is also influenced by nonclimatic factors, careful selection of trees (i.e., avoiding trees with evidence on nonclimatic disturbance, such as fire and insect infestation) can reduce these nonclimatic effects. The common practice of sampling a large number of trees (typically 20-40 per site) also screens out variations in growth that are specific to individual trees, and enhances the common climate-related signal (Fritts, 1976). After collections are complete, samples from each site are dated and measured, then averaged together to create a site chronology. A number of statistical methods are used in the process of compiling a site chronology to further enhance the common climate-related signal. Two of these processes involve eliminating the age-related growth trend in the tree-ring series, and removing the correlation between growth in one year and the next, which is typically due to biological processes (Fritts, 1976).

To reconstruct streamflow from tree rings, variations in year-to-year growth – represented by one or more tree-ring chronologies – are calibrated with an instrumental streamflow record using some type of a regression equation to generate a transfer function. The transfer function is then used to reconstruct the streamflow variable back in time for the length of the tree-ring record. The skill of the reconstruction is evaluated by comparing observed instrumental values and values produced by the reconstruction. An example of this is given in Figure 1 for Clear Creek, a tributary of the South Platte River and the main source of water for the City of Westminster, located just north of Denver, Colorado. Reconstruction skill is quantified through a number of statistics. One of the statistics used is the $r^2$ statistic, which measures the amount of variance in the instrumental record that is explained by the reconstruction model. In the example shown in Figure 1, the variance explained is 61 percent, which is considered good (useful variance explained values typically range from about 40-70 percent). Reconstruction models are commonly validated with instrumental data not used in the calibration process. The Clear Creek reconstruction was validated using a split-sample technique, in which regression models with the same predictor variables were calibrated on the years 1912-1949 and verified on the years 1947-1980, and then calibrated on the years 1947-1980 and verified on the years 1912-1946. The variance explained for the full model and both calibration and verification periods for split models were similar and average about 60 percent (Table 1).

Climate conditions that are most limiting to tree growth (such as low-flow conditions) tend to be duplicated more accurately in the reconstructions than extremes of the opposite sign (such as high-flow extremes). This can be seen in Figure 1, where low flow values for years such as 1922, 1925, and 1963 are closely matched by the reconstructed values, while high flow for years such as 1914, 1921, and 1957 are underestimated by the reconstruction. In general, extreme values tend to be muted as a result of the regression process and as a consequence, reconstructions are usually a conservative estimate of past variability. More complete discussions of dendrohydrological reconstruction techniques can be found in Loaiciga *et al.* (1993) and Meko *et al.* (1995).

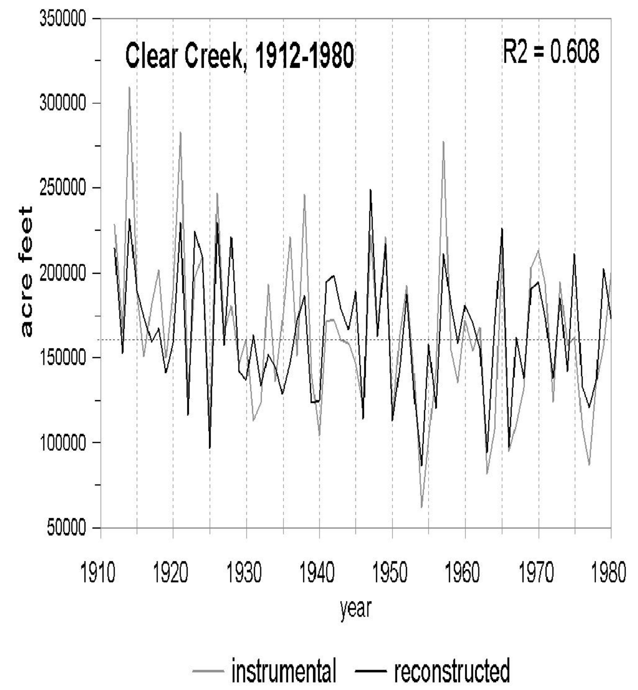



Figure 1. Comparison of the Instrumental Record (gray line) and the Reconstructed Record (black line) for Clear Creek Total Annual Flow, 1912-1980. The tree-ring reconstruction explains 61 percent of the variance in the instrumental record.

DENDROHYDROLOGICAL RECONSTRUCTIONS

Dendrohydrological techniques have been used for a number of streamflow reconstructions in the U.S. In the eastern U.S., streamflow reconstructions have been generated for the Potomac River (Cook and Jacoby, 1983), the Occoquan River in Virginia (Phipps, 1983), and the White River in Arkansas (Cleaveland and Stahle, 1989; Cleaveland, 2000). Dendrohydrologic studies for the western U.S. include reconstructions for the Upper Colorado River basin (Stockton and Jacoby, 1976); the Salt, Verde, and Upper Gila Rivers in Arizona (Smith and Stockton, 1981; Meko and Graybill, 1995); the Sacramento River basin (Earle and Fritts, 1986; Earle, 1993); and southern California basins (Michaelsen *et al.,* 1990). These reconstructions have provided valuable insights on the long-term characteristics of streamflow, perhaps most clearly illustrated by the Upper Colorado River streamflow reconstruction (Stockton and Jacoby 1976). This reconstruction indicated that the Colorado River Compact of 1922 was based on a period of anomalously high flow (1906-1922) when viewed in the context of the 400-year reconstruction. This finding has important implications for water management in the future.

Figure 2 shows the full reconstruction of Clear Creek total annual streamflow from 1685 to 1987. The reconstruction reflects 20th Century periods of low flow (mid-1960s, 1950s, 1930s), but these low flow extremes appear to be moderate compared to low flow years in previous centuries. In particular, there are several episodes of persistent and extreme low flow values in the 19th Century during the 1840s and the 1880s. The distribution of the lowest 20 three-year running averages of streamflow by half centuries is shown in Figure 3. Although the first period and last periods – 1685-1700 and 1951-1980 – are admittedly shorter than the rest, the distribution of extreme three-year low flow averages displays a clustering of extreme values in the 19th Century. The extreme events in the 20th Century are primarily due to the persistence of low flow during the 1950s drought. This reconstruction suggests that the 20th Century record of Clear Creek streamflow may not be representative of flow in past centuries, and that it might be wise to be alert to the possibility of more persistent low flow events in the future.

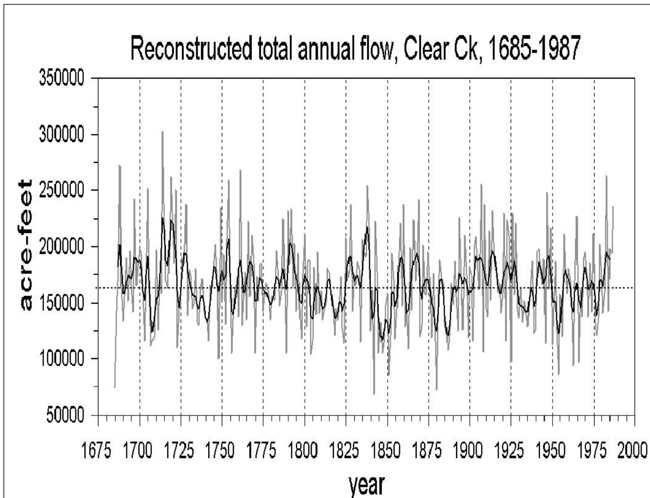



Figure 2. Tree-Ring Reconstruction of Clear Creek Total Annual Flow, 1685-1987. The gray line represents the annual values and the black line represents smoothed values.

TABLE 1. Variance Explained ($r^2$) in Instrumental Record by Full Model and Two Split Models. The split model results compare the variance explained for the calibration periods with that for data not included in the calibration, the verification period data.

| | Split Model 1 | | Split Model 2 | |
|---|---|---|---|---|
| **Full Model 1912-1987** | **Calibration 1912-1946** | **Verification 1947-1987** | **Calibration 1947-1987** | **Verification 1912-1946** |
| 0.608 | 0.573 | 0.596 | 0.682 | 0.537 |

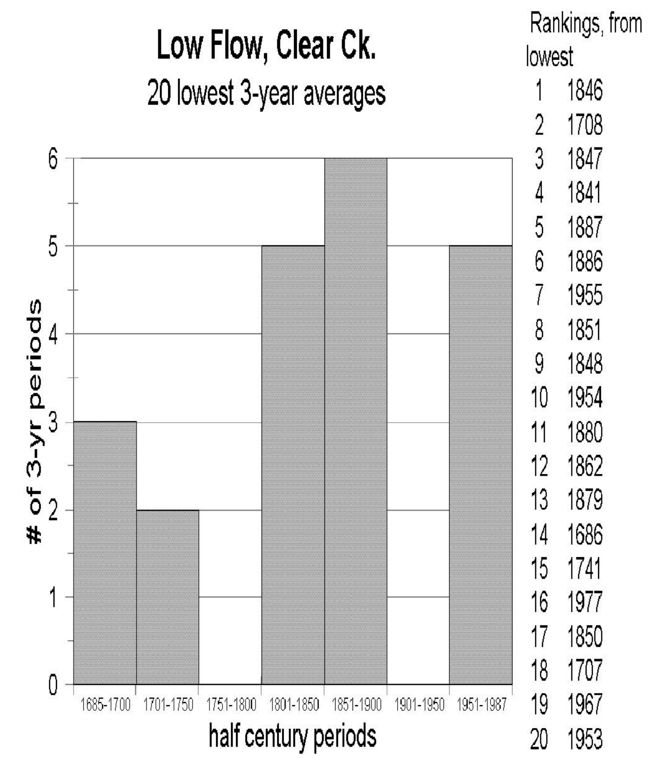



Figure 3. Distribution of the 20 Lowest Three-Year Averages of Total Annual Flow for the Clear Creek Reconstruction. the graph shows the number of these extreme events per half century (the first and last periods are not full half centuries). The columns on the right show the actual rankings (lowest to highest values), with the years listed representing the second year of the three-year average.

## CONCLUSIONS

Tree-ring reconstructions of hydrologic variability have proven to be extremely useful for extending records of streamflow. These extended records help us better understand the range of natural streamflow variability, and are vital for assessing the representativeness of the 20th Century record. Besides offering a long-term perspective, these reconstructions also allow analyses that can explore distributional and probability characteristics of low-flow duration and extreme events for longer time scales (Loaiciga *et al.,* 1993).

Although tree-ring reconstructions of streamflow offer invaluable insights on the long-term and lowrequency behavior of streamflow, further work is needed to increase the usefulness of these records for water resource management and planning. Currently, the feasibility of reconstructing streamflow and streamflow-related variables, such as April 1 snow water equivalent and n-day low flows, is being investigated. Other research challenges involve the refinement of the reconstructed values so that they may be more useful in hydrologic modeling.

## LITERATURE CITED

Cleaveland, M.K. and D.W. Stahle, 1989. Tree Ring Analysis of Surplus and Deficit Runoff in the White River, Arkansas. Water Resources Research 25:1391-1401.

Cleaveland, M.K., 2000. A 963-Year Reconstruction of Summer (JJA) Streamflow for the White River, Arkansas. The Holocene 10:33-41.

Cook, E.R. and G.C. Jacoby, 1983. Potomac River Streamflow Since 1730 as Reconstructed by Tree Rings. Journal of Climate and Applied Meteorology 22:1659-1672.

Earle, C.J., 1993. Asynchronous Droughts in California Stream flow as Reconstructed From Tree Rings. Quaternary Research 39:290-299.

Earle, C.J. and H.C. Fritts, 1986. Reconstructed Riverflow in the Sacramento River Basin Since 1560. Report to California Department of Water Resources, Agreement No. DWR B55398, Laboratory of Tree-Ring Research, Univ. of Arizona, 122 pp.

Fritts, H.C., 1976. Tree Rings and Climate. Academic Press, London, United Kingdom.

Loaiciga, H.A., L. Haston, and J. Michaelsen, 1993. Dendrohydrology and Long-Term Hydrologic Phenomena. Reviews of Geophysics 31:151-171.

Meko, D. and D.A. Graybill, 1995. Tree-Ring Reconstructions of Upper Gila River Discharge. Water Resources Bulletin 31:605-615.

Meko, D., C.W. Stockton, and W.R. Boggess, 1995. The Tree-Ring Record of Severe Sustained Drought. Water Resources Bulletin 31:789-801.

Michaelsen, J., H.A. Loaiciga, L. Haston, and S. Garver, 1990. Estimating Drought Probabilities in California Using Tree Rings. California Dept. of Water Resources Report B-57105, Dept. of Geography, Univ. of California, Santa Barbara, California, 220 pp.

Phipps, R.L., 1983. Streamflow of the Occoquan River in Virginia as Reconstructed From Tree-Ring Series. Water Resources Bulletin 19:735-743.

Smith, L.P. and C.W. Stockton, 1981. Reconstructed Stream Flow for the Salt and Verde Rivers From Tree-Ring Data. Water Resources Bulletin 17:939-947.

Stockton, C.W. and G.C. Jacoby, 1976. Long-Term Surface Water Supply and Streamflow Levels in the Upper Colorado River Basin. Lake Powell Research Project Bulletin No. 18, Inst. of Geophysics and Planetary Physics, University of California, Los Angeles, California, 70 pp.

AUTHOR LINK Connie Woodhouse
NOAA Paleoclimatology Program
National Geophysical Data Center
325 Broadway E/GC
Boulder, CO 80303
(303)497-6297 / Fax: (303)497-6513

E-MAIL woodhous@ngdc.noaa.gov

**Connie Woodhouse** is a physical scientist with the NOAA Paleoclimatology Program at the National Geophysical Data Center in Boulder, Colorado. She is also a research scientist at the Institute of Arctic and Alpine Research at the University of Colorado. Her research interests include paleoclimatic reconstructions of climate and streamflow, with a emphasis on the use of tree rings for reconstructions in the central and western United States. She holds a PhD in Geosciences from the University of Arizona.

❖ ❖ ❖

# LONG-TERM WATERSHED RESEARCH IN USDA-AGRICULTURAL RESEARCH SERVICE

**Charles W. Slaughter and Clarence W. Richardson**

## INTRODUCTION AND RATIONALE

Sustained hydrologic research founded on high-quality data is integral to the national research program of the USDA Agricultural Research Service (ARS). A fundamental component of ARS hydrologic research is its national network of instrumented experimental watersheds and field research facilities.

While ARS was formally established as a separate Agency within USDA in 1954, several of its hydrologic research facilities predate the agency, having been established in the 1930s. In 1959 Congress recognized the need for sustained scientific research and for data base development to support hydrologic process research in agricultural and rangeland watersheds. The rationale outlined in Senate Document 59 (86th Congress, 1959) stressed the urgent need to determine soil and water problems of regional and national importance and to carry out research leading to the solution of these problems, and called for "prompt and orderly application of conservation practices necessary for the protection of the Nations's most vital natural resources – soil and water" (Senate Document 59:1). The report recommended that "Special attention should be given to hydrologic research of agricultural watersheds..." and that four to six major experimental watersheds be established and located in the Northeast, the Southeast, the Southern Great Plains, the North Central States, the Pacific Northwest, and the Southwest of the U.S. (86th Congress, 1959). ARS consequently invested in an unprecedented national field instrumentation infrastructure involving spatially extensive precipitation and snowfall, climate, soil moisture, ground water recharge, sediment yield, and streamflow measurement and analysis. Guidelines for many aspects of field hydrology research were summarized by Brakensiek *et al.* (1979). Much of the ARS investment was in six regional Hydrology Research Centers, which evolved into a network of Research Watersheds. Those regional Research Watersheds are complemented by hydrologic research facilities which may not be "research watersheds" but that conduct fundamental hydrologic, hydraulic, and climate research. In this paper we summarize the current national ARS research watershed network.

*Experimental watersheds are outdoor laboratories in which observation and experimentation can proceed hand-in-hand with model development and analysis.*

## THE ARS RESEARCH WATERSHED NETWORK

Nine long-term research watershed facilities (Figure 1) form the backbone of the ARS hydrology program. These watershed locations are complemented by watershed-related hydrologic process research conducted at additional ARS locations throughout the nation. These facilities and experimental watersheds provide long-term, instrumented research sites representing major biogeographic areas of the conterminous U.S., and typically are available to university, private and other federal investigators for collaborative research.

◆ *North Appalachian Experimental Watershed, Ohio.* The North Appalachian Experimental Watershed was established in 1935 on 419 ha in Coshocton County, Ohio, to study and develop methods for conserving soil and water resources. Research accomplishments include over 35 years of research on effectiveness of no-till agriculture to reduce soil loss from cultivated slopes, extensive research on effects of surface mining and mined land reclamation on hydrology, water quality and sediment yield, and over 30 years of research on movement and transformation of nutrients and pesticides in agricultural soil water and runoff. A 60-year data base of measurements from rain gauges, flumes and weirs, lysimeters, and climate stations provides a frame of reference for research to develop knowledge of basic water, sediment, and chemical movement and to support transport model development and validation.

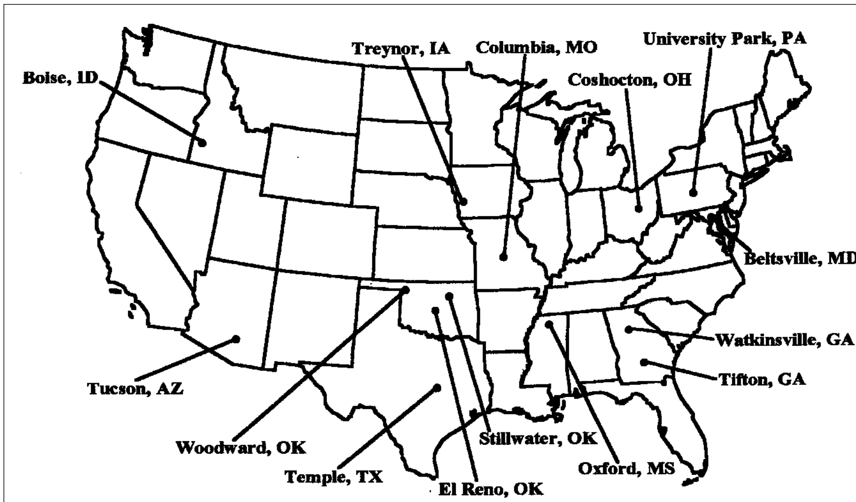



Figure 1. Primary Hydrology and Hydraulics Research Locations of USDA Agricultural Research Service.

◆ *Blackland Experimental Watershed, Texas.* The Blackland Experimental Watershed was established in 1937 in a setting selected to be representative of heavy clay soils in a subhumid climate, with the initial purpose to determine effects of conservation practices on surface runoff, erosion, and sediment yield. An array of 20 individual basins, 55 ha to 18 km$^2$ drainage area, is instrumented and monitored to supply data surface runoff, ground water recharge, clay soil cracking, and water quality for hydrologic and hydraulic modeling. Over 60 years of hydrologic data are available for analysis. Current data are telemetered in near-real-time to a central data bank. The Blackland Experimental Watershed is operated by the Grassland Soil and Water Research Laboratory in Temple, Texas.

◆ *Walnut Gulch Experimental Watershed, Arizona.* The 150 km$^2$ Walnut Gulch Experimental Watershed was established at Tombstone, Arizona, in 1953 in a setting representative of semiarid southwestern U.S. grass and shrub rangelands. The Watershed is intensively instrumented for precipitation and runoff monitoring, and a data telemetry system is being installed. Research addresses erosion and sedimentation processes, water quality and remote sensing, and supports development of simulation models for resource management, and regional remote sensing research initiatives. Nearly 50 years of basic climate and hydrology data are available. Walnut Gulch Experimental Watershed is operated by the Southwest Watershed Research Laboratory, Tucson, Arizona.

◆ *Reynolds Creek Experimental Watershed, Idaho.* The Reynolds Creek Experimental Watershed was established in 1960 in the Owyhee Mountains of the interior Pacific Northwest, in a site selected to be representative of high-relief semi-arid rangelands with highly diverse geology, topography, soils, climate, vegetation, ownership, and land use in which seasonal snow and frozen soil processes dominates the annual hydrologic cycle. Research addresses watershed hydrologic processes and management issues in a hierarchy of intensively-instrumented catchments from 1.2 ha to 238.7 km$^2$ drainage area, with automated data telemetry to a central archive. A comprehensive 35-year hydrologic and climate data base is currently (2000) being prepared for publication and posting on an anonymous FTP site. These data support detailed hydrologic process research; longitudinal (time trend) studies of climate, precipitation, snow ablation and water yield; streamflow regime and vegetation development; and evaluation of change of landscape attributes including water yield and vegetation community composition and biological productivity in response to forcing factors such as specific management practices, weather events, and climate change. Reynolds Creek Experimental Watershed is operated by the Northwest Watershed Research Center, Boise, Idaho.

◆ *Little Washita Experimental Watershed, Oklahoma.* The 610 km$^2$ Little Washita River Watershed, the largest in the ARS network, was established in 1961 to be representative of the extensive Southern Great Plains. A major original objective was to determine downstream consequences of PL83-566 floodwater retarding structures. In the 1990s instrumentation was augmented to support research on climate variation and watershed hydrology, and research now includes support of large-scale multi-agency remote sensing-based hydrologic experiments. Instrumentation on the Little Washita includes 42 meteorological stations providing telemetered 15-minute data in support of ARS research and the Oklahoma Mesonet. The Little Washita Experimental Watershed is operated by the Grazingland Research Laboratory, El Reno, Oklahoma.

◆ *Deep Loess Research Station Watersheds, Iowa.* Four field-size watersheds, 30.3 ha to 60.7 ha drainage area, were instrumented beginning in 1964 to determine factors causing gully and channel erosion and evaluate effects of land treatment and cropping practices on that erosion and on surface and ground water quality in cropped loess lands of the North Central Corn Belt. Treatments (management systems) have been maintained for up to 30 years to permit long-term evaluation of effectiveness for soil conservation. The watersheds are operated by the Deep Loess Research Station, National Soil Tilth Laboratory, Treynor, Iowa.

◆ *Little River Watershed, Georgia.* The 335 km$^2$ Little River Watershed was established in 1966, at a site selected to represent the Coastal Plain Region of the southeastern U.S., to determine relationships among precipitation, runoff, and water quality in Coastal Plain agricultural watersheds. Research has supported major model development including CREAMS and GLEAMS and REMM for simulation of physical, chemical, and biological processes of agricultural systems. Long-term hydrologic data bases have been developed for eight watersheds, ranging from 2.6 km$^2$ to 335 km$^2$ drainage area. Little River Watershed is operated by the Southeast Watershed Research Laboratory, Tifton, Georgia.

◆ *Mahantango Creek WE-38 Watershed, Pennsylvania.* The 7.4 km$^2$ Watershed WE-38 of Mahantango Creek Watershed was established in 1968 in the Appalachian Valley and Ridge physiographic province, to support research on water quality and hydrology of mixed agricultural, urban and municipal landscapes in New England. A 30-year data base of climate, stream flow, ground water, and water quality information is available. Mahantango Creek WE-38 Watershed is operated by the Pasture Systems and Watershed Management Research Unit, University Park, Pennsylvania.

◆ *Goodwin Creek Experimental Watershed, Mississippi.* The 21.3 km$^2$ Goodwin Creek Experimental Watershed was established in 1980 as a part of the "Streambank Erosion Control Evaluation and Demonstration Project" authorized by Public Law 93-251. The U.S. Army Corps of Engineers provided major construction funding. Goodwin Creek is representative of mixed land use watersheds throughout the loess region of the Mississippi Alluvial Plain, with excessive upland erosion, steep degrading channels, loss of land due to channel incision and bank caving, and downstream deposition problems. The watershed is partitioned into 14 nested gaged subbasins, 0.053 to 21.3 $km^2$ drainage area; precipitation is monitored with 30 recording raingages in and adjacent to the watershed. In the last decade multi-agency remote-sensing stations have been added to support climate and hydrometeorological research. Goodwin Creek Experimental Watershed is operated by the National Sedimentation Laboratory, Oxford, Mississippi.

Additional ARS hydrologic research is conducted at sites across the U.S. Major research facilities include:

◆ *The Southern Plains Range Research Station,* initially established in 1913 at Woodward, Oklahoma, utilizes a 2094 ha Southern Plains Experimental Range and Field Station in research to develop resource-efficient grazing systems for southern mixed-grass and shortgrass prairie range and pasture systems. Research includes four small watersheds used to analyze runoff, erosion, and water use efficiency.

◆ T*he Southern Piedmont Conservation Research Unit* was established at Watkinsville, Georgia, in 1937 to determine hydrologic impacts of cropping systems in the southeastern U.S., and to improve understanding of chemical, physical, and biological interactions in agricultural systems of the Southern Piedmont region. Research addresses sustainability of agricultural systems at a farm level, and includes instrumented catchments over a scale range from 300 $m^2$ to 2 $km^2$ within the Upper Oconee River Basin of Georgia. The Research Unit is operated by the Phil Campbell, Sr., Natural Resource Conservation Center, Watkinsville, Georgia.

◆ *The Stillwater Outdoor Hydrologic Laboratory* was established in Stillwater, Oklahoma, in 1940 to conduct large-scale hydraulic model studies. The research has included developing design criteria for grassed waterways, and for structures utilized in the USDA NRCS small watershed programs under the Flood Control Act of 1994, Pilot Watershed Program of 1953-54, Watershed Protection and Flood Prevention Act of 1953, and Resource Conservation and Development Program. The Laboratory is widely recognized for contributions to soil and water conservation structure and channel design criteria, and development and validation of hydraulic models. The Laboratory is operated by the ARS Hydraulic Engineering Research Unit, Stillwater, Oklahoma.

◆ *The ARS National Sedimentation Laboratory (NSL),* established in 1959 at Oxford, Mississippi, conducts multidisciplinary hydrologic studies of climate, runoff, erosion, sedimentation, water quality, and ecology in support of the Congressionally-mandated Demonstration Erosion Control (DEC) and Total Maximum Daily Loads (TMDL) Projects in the Yazoo River basin, Mississippi. Most streams and lakes in this basin are ecologically impaired due to channel incision and the movement of sediment and agricultural chemicals from both adjoining and upstream agricultural lands. NSL is conducting a multi-agency program of monitoring and evaluation to reduce flooding, erosion, sedimentation, and contamination problems by applying environmentally sound management practices. Research is focused on the 783 $km^2$ Yalobusha River basin, a main tributary of the Yazoo.

◆ *The Cropping Systems and Water Quality Research Unit, Columbia, Missouri,* established the 73 $km^2$ Goodwater Creek Experimental Watershed in 1969, in rolling claypan and loess croplands to explore precipitation, runoff, and ground water relationships in north-central Missouri farmlands. The research program has been incorporated into the Missouri Management System Evaluation Area with emphasis on water quality and on scaling research from field to area and state scales.

◆ *The ARS Hydrology Laboratory* was established in 1961 at Beltsville, Maryland, to provide a national center for agricultural hydrologic research and analysis. Research addresses developing improved methodologies for predicting water yield from agricultural lands and for monitoring and evaluating the impact of management practices and environmental change on water resources. The Hydrology Laboratory operates four 4-ha agricultural watersheds for research on climate, ground water flux, surface runoff, energy flux, and remote sensing for evaluation of soil moisture. The Hydrology Laboratory maintains the ARS Water Database, a national archive of precipitation and streamflow data from ARS research watershed, containing over 16,000 station-years of data for watersheds ranging from 0.2 ha to 12,400 $km^2$. Those data are available at http://hydrolab.arsusda.gov/wdc/arswater.html. The Hydrology Laboratory is operated by the National Resources Institute, Beltsville Agricultural Research Center, Beltsville, Maryland.

Additional hydrologic and soil and water conservation research is conducted at ARS research units in Morris, Minnesota; Beaver, West Virginia; Lafayette, Indiana; Florence, South Carolina; Las Cruces, New Mexico; Fort Collins, Colorado; Lincoln, Nebraska; Cheyenne, Wyoming; Phoenix, Arizona; Kimberly, Idaho; Burns, Oregon; Corvallis, Oregon; Pendleton, Oregon; Fresno, California; Riverside, California; Prosser; Washington; and Pullman, Washington.

## REDUNDANCY?

Given the extreme diversity in landscape characteristics and ecological conditions which exists across the continental United States, it is appropriate that individual research programs be paralleled (*not duplicated*) in some respects in markedly different environmental settings. For example, research at Reynolds Creek Experimental Watershed is paralleled and augmented by research in Walnut Gulch Experimental Watershed. Both locations address issues of hydrology of rangeland watersheds, but Walnut Gulch focuses on arid rangelands of the extreme southwestern U.S., while Reynolds Creek addresses snow-fed hydrologic systems and seasonally frozen soils of the interior Pacific Northwest and northern Great Basin with highly heterogenous climate, land ownership, land use, and management.

## CONCLUSIONS

These highly instrumented ARS experimental watersheds are fundamental tools in developing better understanding of hydrologic process for important biogeographic regions. Experimental watersheds are outdoor laboratories in which observation and experimentation can proceed hand in hand with model development and analysis. The value of experimental watersheds was emphasized by the National Research Council (1991) which concluded that "hydrologic science is currently data limited." The National Research Council (1997) has specifically cited ARS watershed research as offering promising areas for collaboration with other agencies, while the Subcommittee on Global Change Research (1999), has repeatedly recognized the importance of long-term terrestrial monitoring and research to understand change over time. With the increasing importance of national issues such as water availability, environmental quality, food production, and climate change, the composite network offers unparalleled capabilities to examine potential impacts and changes both regionally and nationally.

The ARS experimental watersheds complement similar long-standing programs of other agencies including the USDA Forest Service, with its legacy of Experimental Forests and Research Watersheds; the U.S. Geological Survey, with its Vigil Network, Benchmark Basins and WEBB basin research programs; the USDI National Park Service's research program; and the National Science Foundation's Long-Term Ecological Research (LTER) program.

It might be argued that such a research network can only be sustained over the long term at the federal level. While state and local governments, universities, and private organizations will continue to need watershed-based research. Few, if any, have the responsibility or resources to conduct an integrated national watershed research program addressing critical national problems of natural resource conservation, environmental protection, sustainable agriculture, and rural development. The ARS watershed network provides unique data, a reserve of knowledge, and a body of scientific information which would otherwise not be available on a national basis.

## LITERATURE CITED

Brakensiek, D.L., H.B. Osborn, and W.J. Rawls, 1979. Field Manual for Research in Agricultural Hydrology. Agriculture Handbook 224, U.S. Department of Agriculture, Washington, D.C., 550 pp.

86th Congress, 1959. Senate Document 59. Facility Needs – Soil and Water Conservation Research, 1959

National Research Council, 1991. Opportunities in the Hydrologic Sciences. Water Science and Technology Board, Commission on Geosciences, Environment, and Resources. National Academy Press, Washington, D.C., 348 pp.

National Research Council, 1997. Watershed Research in the U.S. Geological Survey. Water Science and Technology Board, Commission on Geosciences, Environment, and Resources. National Academy Press, Washington, D.C., 86 pp.

Subcommittee on Global Change Research, 1999. Our Changing Planet. The FY2000 U.S. Global Change Research Program Implementation Plan and Budget Overview. Committee on Environment and Natural Resources, National Science and Technology Council, Washington D.C., 100 pp.

AUTHOR LINK

Charles W. Slaughter
1112 East Hays Street
Boise, ID 83712
(208) 383-1084 / Fax: (208) 334-1502

Clarence W. Richardson
USDA-REE-ARS-SPA-S&WR Lab
Lab Director
808 Blackland Road
Temple, TX 76502-9601
(254) 770-6500 / Fax: (254) 770-6561

E-MAIL

macwslaugh@icehouse.net
richards@brc.tamus.edu

Chuck Slaughter is Adjunct Professor, University of Idaho (Boise). Past assignments include Research Leader, Northwest Watershed Research Center, USDA Agricultural Research Service, Boise, Idaho, and Principal Watershed Scientist, Institute of Northern Forestry, Fairbanks, Alaska. His research has included snow and ice hydrology, landscape/stream interactions, fluvial geomorphology, and interactions of renewable resources management with rangeland, boreal, and high-latitude watershed systems. He holds a B.S. in Forest Management from Washington State University, and a Ph.D. in Watershed Management from Colorado State University.

Clarence Richardson is an Agricultural Engineer and Laboratory Director with the USDA Agricultural Research Service, Grassland Soil and Water Research Laboratory in Temple, Texas. His research deals with agricultural hydrology and weather simulation. He holds B.S. and M.S. degrees in Agricultural Engineering from Texas A&M University and a Ph.D. in Civil Engineering from Colorado State University. He is a Registered Professional Engineer in Texas.

❖ ❖ ❖


The Leader in Water Instrumentation
Water Level Sensors
Submersible Pressure Transducer
Wells, Pressure/Level Control, Liftstations, SCADA
Amplified 2-Wire, 4-20 mA
High Accuracy
Temperature & Barometric Pressure Compensated
Samplers
Wastewater, Stormwater and Environmental Monitoring
Composite and Discrete Samples
Portable and Stationary Applications
24-Bag Sampler, Refrigerated and Open Channel Flow Options
WaterLogger
Datalogger & Submersible Pressure Transducer
Groundwater, Surface Water, Sewers and Stormdrains
16,000 Readings; Battery Powered
EZ-Windows Software Included; Cable Lengths to 500'
Pipe Pressure and Weir Stick Options
Dataloggers & Systems
Records 8 Channels
Weather, Water Quality, Level and More
Weather-Proof Enclosure
Battery or Solar Powered
EZ-Windows Software Included
Global Water
Accurate. Rugged. Reliable.
Level. Flow. Samplers. Water Quality. Weather. Remote Monitoring. Control.
For more information,
visit our complete online catalog
www.globalw.com
or call
(800) 876-1172
7:30 AM to 4 PM Pacific Time
International: US (916) 638-3429
FAX: (916) 638-3270
E-mail: globalw@globalw.com
Our goal is to provide you with the finest water instrumentation at a reasonable price. Our products are always fully supported and 100% guaranteed. Our staff will be pleased to help you meet the requirements of your particular application.

# THE NATIONAL ATMOSPHERIC DEPOSITION PROGRAM A LONG-TERM MONITORING PROGRAM IN SUPPORT OF RESEARCH ON EFFECTS OF ATMOSPHERIC CHEMICAL DEPOSITION

**Van C. Bowersox**

## INTRODUCTION

Every year the National Atmospheric Deposition Program (NADP) fulfills more than 10,000 requests for data, maps, and other information through its Internet site (http://nadp.sws.uiuc.edu). Requests come from scientists, policy makers, students, and other people who use NADP data to address important questions about the chemicals in precipitation and their effect on our environment. Now in its third decade, the NADP provides the only long-term nationwide record of the chemistry of U.S. precipitation. The length and quality of this record are due to the commitment and steadfast efforts of site sponsors, operators, and laboratory and program office staff who have spent countless hours collecting and measuring samples, ensuring high data quality, and summarizing and reporting data.

Why does NADP keep such diligent vigil over what's in our precipitation? The answer lies in our need to monitor how human activities and the forces of nature affect our air and precipitation quality – important measures of the health of our atmosphere. The information we gain will equip us to make more responsible decisions about how to preserve and improve our air quality and how to manage our agricultural, forest, aquatic, cultural, and energy resources.

## BACKGROUND

### Getting Started by Working Together

In the mid-1970s, North American scientists grew concerned over reports of increasing rain and snow acidity and the potential for environmental damage from acidic deposition. An expert panel convened by the National Academy of Sciences in 1976 recommended a nationwide network be installed to measure spatial and temporal trends in atmospheric deposition. Scientists could use data from this network to examine the connection between pollutant emissions, precipitation chemistry, and potential environmental impacts.

> *Atmospheric deposition significantly affects the supply of both essential and potentially injurious compounds available to natural systems.*

In 1977, State Agricultural Experiment Stations (SAES) led the effort to establish just such a network by forming the NADP, a cooperative program to measure chemical changes in atmospheric deposition and its effects on agricultural and forested land and surface waters. Joining the effort as this program took shape were the U.S. Departments of Agriculture (Forest Service), Energy, Commerce, and Interior; the U.S. Environmental Protection Agency; universities; and industries.

Organizers designed the network so that sampling stations would be representative of the region where they were located. This meant avoiding large pollutant sources (cities and industrial and utility plants), local influences (highways and animal confinements), and on-site obstructions (buildings and trees). Recognizing the value of cooperative research, organizers also sought locations with ongoing, related ecological research. To ensure data comparability, each site agreed to comply with NADP siting criteria, equipment specifications, sampling protocols, and to use a single analytical laboratory – the Central Analytical Laboratory (CAL) at the Illinois State Water Survey. The first sites in the NADP network began operations in the summer of 1978, and 22 sites were operational by the end of the year.

### Building and Sustaining Support Through Cooperation

Buoyed by the early successes of the NADP, the SAES endorsed the program as a nationwide or Interregional Project (IR7) in 1982. This endorsement accompanied growth of the network to 106 sites in 41 states, a site in American Samoa, and three sites alongside Canadian network sites in Alberta, Ontario, and Nova Scotia. At about the same time, the U.S. Geological Survey was charged with leading the development of a National Trends Network (NTN) under the new federal National Acid Precipitation Assessment Program (NAPAP). Federal agencies worked together in this comprehensive assessment to fully understand acid precipitation and develop a scientific basis for reducing its effects. The NTN adopted NADP siting criteria, operating equipment, procedures, and analytical laboratory, and the networks merged with the designation NADP/NTN. Recognizing the need for more sites to measure precipitation chemistry in all ecoregions, the federal agencies added new sites, particularly in the western United States. By the end of 1985, the network had grown to nearly 190 sites. In 1998, the network designation, NADP/NTN, was shortened to NTN.

Today, the NADP is SAES National Research Support Project-3. There are now more than 200 cooperators, including the SAES; federal, state, and local government agencies; universities; tribal organizations; private companies; and other research organizations. These organizations continue to work together toward two common goals:

◆ To characterize geographic patterns and temporal trends in chemical deposition.

◆ To provide chemical deposition data that will support research related to (a) productivity of managed and natural systems; (b) surface and ground-water chemistry, including estuaries; (c) the health of domestic animals, wildlife, and fish; (d) human health; (e) visibility and materials degradation; and (f) pollutant source-receptor relationships.

## NADP TODAY

### Not Just Acid Rain

Today we know that many regional and national air quality issues – not just acid rain – involve chemical deposition from the atmosphere. The NADP offers the expertise and infrastructure to respond to immediate and emerging needs. For example, NADP responded quickly to requests for precipitation samples from across the U.S. after the 1986 accident at the Chernobyl nuclear plant in the Ukraine. Using these samples, scientists were better able to estimate the amount and distribution of radioactivity that fell across the country. From 1990 through 1991, NADP provided samples from selected states to researchers investigating the presence of herbicides in precipitation. That study provided evidence of significant herbicide concentrations in rainfall. With three precipitation chemistry networks, NADP remains committed to addressing important issues as they emerge.

*National Trends Network (NTN)*

Figure 1 shows the active NTN sites. The network operates 225 sites in 46 states and extends from Puerto Rico and the Virgin Islands in the east to Alaska in the west. Two sites have paired collocated collectors and precipitation gages, a component of the network quality assurance program. Another component is operating network-comparison sites alongside Canadian Air and Precipitation Monitoring Network (CAPMoN) sites in Quebec Province, Canada, and in central Pennsylvania. Collocated and network-comparison sampling are quality assurance activities designed to evaluate the overall precision and comparability of network data.

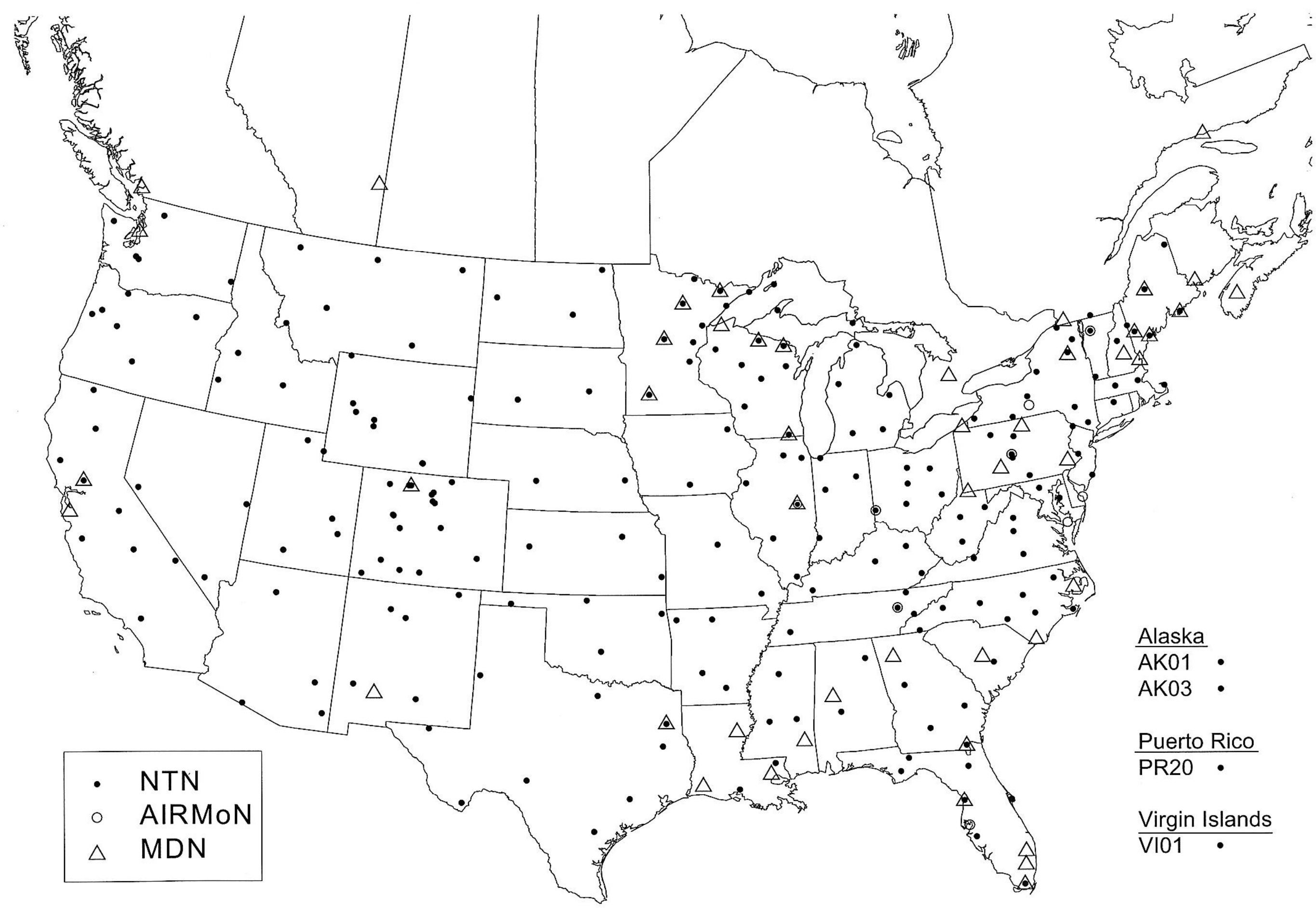



Figure 1. National Atmospheric Deposition Program.

The NTN collects one-week precipitation-only samples and measures daily precipitation amounts. Thirty-two active sites now have more than 20 years of data. The CAL analyzes all NTN samples for the "acid rain" species (free acidity, or pH, sulfate, and nitrate), nutrients (nitrate, ammonium, and orthophosphate), "base cations" (calcium, magnesium, and potassium), sodium, and chloride. These NTN data are used primarily to track spatial and temporal trends in seasonal and annual wet deposition, defining the chemical climate of U.S. precipitation.

*Atmospheric Integrated Research Monitoring Network (AIRMoN)*

Complementing the NTN is the Atmospheric Integrated Research Monitoring Network (AIRMoN), a research network that focuses on detecting how sources and meteorology affect precipitation chemistry. Supported primarily by the National Oceanic and Atmospheric Administration's Air Resources Laboratory, AIRMoN joined NADP in October 1992. It comprises nine sites (Figure 1) that collect samples every day after precipitation occurs. Within hours of collection, AIRMoN samples are refrigerated until analysis for the same constituents as NTN samples. The CAL analyzes all AIRMoN samples.

The AIRMoN data are combined with results from atmospheric models that track air movements. Together, AIRMoN measurements and air parcel trajectories are used to investigate the nature of the relationship between pollutant sources, precipitation chemistry, and wet deposition. This network also evaluates new sample collection and preservation methods designed to arrest the biodegradation of ammonium, an important nutrient, and losses of free acidity.

*Mercury Deposition Network (MDN)*

The Mercury Deposition Network (MDN) joined the NADP in January 1996 and now has 48 sites in 19 states and in six Canadian provinces (Figure 1). The MDN collects one-week precipitation-only samples and measures daily precipitation amounts. Frontier Geosciences, Inc., a laboratory that specializes in trace mercury analyses, reports total mercury concentrations in all MDN samples and methyl mercury in some samples.

Nearly 50 states and provinces have advisories against eating fish from certain lakes because of mercury contamination. In most cases, there are no nearby waste dumps or obvious sources of mercury in the area. Research points to atmospheric deposition as an important source of mercury in many lakes and streams. Even at low levels, mercury can cause lack of coordination, tremors, and speech and hearing impairments. Methyl mercury bioaccumulates, which means that mercury concentration increases as it moves up the food chain from microorganisms to fish to humans. The MDN data enable researchers to examine the importance of the atmospheric transport and deposition of mercury from distant sources as a cause of mercury contamination in lakes and streams where mercury is a problem.

After 20 Years . . . What Have We Learned?

Atmospheric deposition significantly affects the supply of both essential and potentially injurious compounds available to natural systems. It also affects the weathering and corrosion rates of building materials and structures – our cultural resources. Atmospheric deposition affects the nutrient status, growth, and development of plants on land and in surface waters. It often benefits agricultural crops by adding growth-stimulating nutrients. Plant growth also may be stimulated when the acids in precipitation accelerate the weathering of soils, making minerals more readily available. Growth stimulation in certain unmanaged forests, however, may make the trees less hardy and more vulnerable to the stresses of cold weather and disease. Adding nutrients to surface waters may boost algal production that sometimes depletes the oxygen supply below levels that support fish and other aquatic life when these algae die. Fish health and reproductive capacity also may be influenced by the atmospheric deposition of acids and other trace constituents. Where precipitation is acidic, it can speed corrosion of exposed metals and weathering of unprotected stone building surfaces and statues. In these examples, atmospheric deposition has an influence on biological and geological systems, playing an important role in the biogeochemical cycle, and it modifies natural weathering and corrosion processes.

After 20 Years . . . What Are the Issues?

Data from NADP's three networks are being used to address contemporary issues such as these:

- Evaluating the effectiveness of sulfur and nitrogen oxides emissions reductions specified in the 1990 Clean Air Act Amendments on the sulfate, nitrate, and free acidity (pH) concentrations of precipitation.
- Updating recommendations for sulfur fertilizer applications in light of lower sulfur amounts deposited by precipitation.
- Estimating the amount and importance of atmospheric inorganic nitrogen deposited to coastal and inland watersheds such as the Chesapeake Bay and Mississippi River drainages, where nutrients have enhanced algal growth and degraded water quality.
- Exploring the causes of downward base cation trends in precipitation and their effects on the fertility of some acidic forest soils and forest health. Assessing the response of forests and lakes to the changing chemistry of precipitation.
- Examining the relationship between pollutant sources, air quality, precipitation quality, and wet deposition.
- Determining wet deposition rates of mercury to lakes and streams and evaluating the relative importance of atmospheric deposition and other sources of mercury in causing high mercury levels in fish.

## CONCLUSIONS

The dedication of NADP cooperators continues to make NADP one of the most successful cooperative programs in the U.S. Here's what scientists have said in review of the NADP, "The monitoring program is perhaps the most significant long-term, continuous, and comprehensive sampling and analysis program to be undertaken in the environmental sciences" (Jansen *et al.,* 1988). Extending this record so that future peer reviewers can say no less is the challenge of every person involved with the NADP today.

## LITERATURE CITED

Jansen, J., K. Aspila, M. Hoffman, G. Ohlert, and J. Winchester, 1988. Session Summary Report. NAPAP Task Group IV, Wet Deposition Monitoring Peer Review. National Acid Precipitation Assessment Program, 722 Jackson Place, NW, Washington, D.C.

AUTHOR LINK
Van C. Bowersox
Coordinator, NADP
Illinois State Water Survey
2204 Griffith Drive
Champaign, IL 61820
217/333-7873 / Fax: (217) 244-0220

E-MAIL
sox@sws.uiuc.edu

**Van Bowersox** serves as the Coordinator of the National Atmospheric Deposition Program and is a Senior Scientist at the Illinois State Water Survey on the campus of the University of Illinois in Champaign, Illinois. His interests are in the scavenging of gases and aerosols by precipitation and in the temporal trends and spatial distributions of precipitation chemistry and wet deposition fluxes. Van has a B.S. in Chemistry and Education and a M.S. in Meteorology from Pennsylvania State University.

SELECTED YEAR 2000 PUBLICATIONS USING NADP DATA.

Barracato, J., 2000. Inside Rain – Working with Precipitation Chemistry Data. (Curriculum guide for grades 9-12) National Science Teachers Association, Arlington, Virginia, 122 pp.

EPA, 2000. Deposition of Air Pollutants to the Great Waters – Third Report to Congress. EPA-453/R-00-005, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, 260 pp.

GAO, 2000. ACID RAIN – Emissions Trends and Effects in the Eastern United States. Report to Congress, U.S. General Accounting Office, Washington, D.C., 33 pp.

Huntington, T.G., 2000. The Potential for Calcium Depletion in Forest Ecosystems of Southeastern United States: Review and Analysis. Global Biogeochemical Cycles 14(2):622-638.

Lynch, J.A., V.C. Bowersox, and J.W. Grimm, 2000. Acid Rain Reduced in the Eastern United States. Environmental Science and Technology 34(6):940-949.

NADP, 2000. Nitrogen in the Nation's Rain. NADP Program Office, Illinois State Water Survey, 2204 Griffith Drive, Champaign, Illinois, 14 pp.

Special Issue, National Atmospheric Deposition Program (NADP), 2000. Atmospheric Environment 34(11):1661-1737 (seven articles).

❖ ❖ ❖

# DATASETS FROM LONG-TERM ECOLOGICAL RESEARCH (LTER) SITES AND THEIR USE IN ECOLOGICAL HYDROLOGY

**David A. Post, Julia A. Jones, and Gordon E. Grant**

We believe that communication among ecosystem scientists is hampered by the lack of ecologically relevant descriptors of hydrologic properties. To partly remedy this situation, we are attempting to define hydrologic response in ecologically meaningful ways. What this means is :

◆ How do hydrological processes, including the types, rates, timing, and pathways of water throughput at various timescales, influence ecological processes?

◆ What feedbacks and constraints are imposed by ecosystems and landforms on hydrologic processes, including the role of vegetation as a mediator of water input, storage, and usage?

Work in ecological hydrology brings the diverse perspectives of ecologists and hydrologists together into a common framework, and galvanizes insights relevant to terrestrial and stream ecology, geomorphology and biogeochemistry of landscapes, and regionalization and modeling of hydrologic processes over wide space and time scales.

Small paired experimental watersheds, with their long-term monitoring systems for data collection and their integrated ecosystem approach to analysis, have been key to recent advances in ecological hydrology. Decades of work at sites such as Hubbard Brook (Likens *et al.,* 1977; Bormann and Likens, 1979; Likens, 1983) and Coweeta (Swank and Crossley, 1988) have provided fundamental insights into site-level interactions among hydrology, climate, and ecology and their response to human uses. Previous meta-analyses have emphasized the variability in streamflow responses to landuse and climate variability among these in-depth site-level studies (e.g. Hewlett and Hibbert, 1967; Meyer *et al.,* 1993).

Significant advances in ecological hydrology will require collaborative efforts to bring together the original long-term datasets from geographically diverse sites in order to examine them in a common analytic framework. Original long-term datasets include hydrologic and climatic records, as well as data on vegetation and landforms. A common analytic framework means putting data in comparable formats and combining them in comparative intersite statistical and modelling analyses to derive general principles.

To achieve this, a study is currently underway to identify interactions among vegetation, climate, and streamflow for the sites shown in Figure 1. Thus far, work has concentrated on the seasonal variations among the Andrews, Coweeta, Hubbard Brook, Luquillo and Caspar Creek sites, which span a range of precipitation amounts, types, and timing as well as a range of forest vegetation types. However, data have now been collected

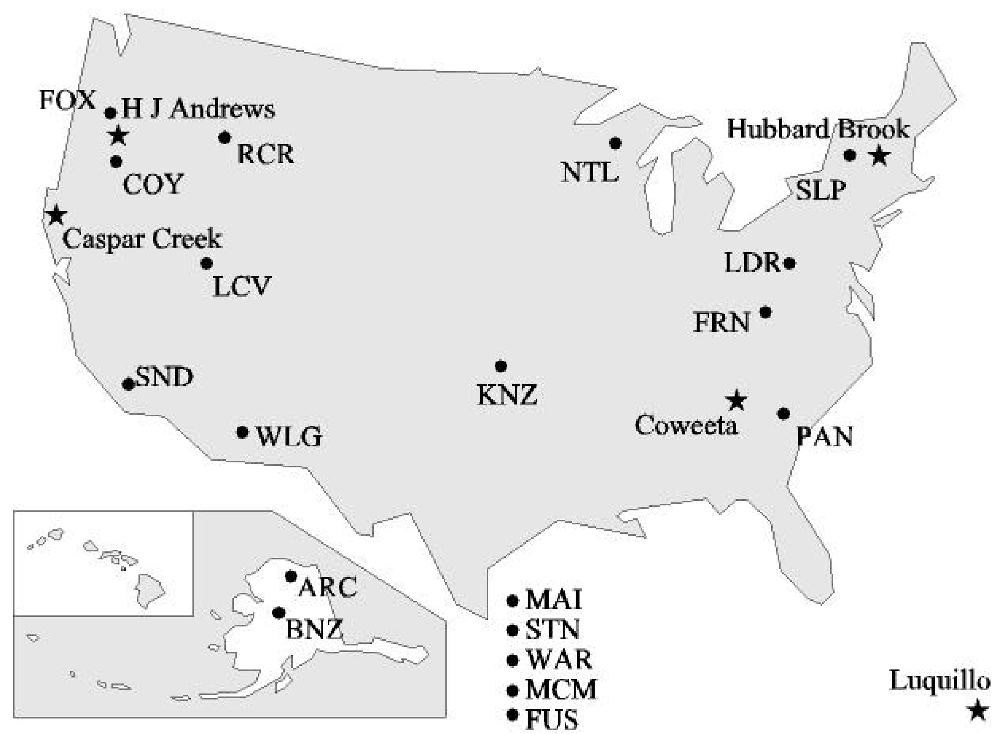



Figure 1. Sites Spanning a Range of Biome Types and Hydroclimatological Regimes Where Long-Term Ecological and Hydrologic Research Have Been Underway for as Long as Six Decades. Sites examined in this paper (marked with a star) include H. J. Andrews, OR; Coweeta, NC; Hubbard Brook, NH; Luquillo, PR; and Caspar Creek, CA. Sites that are currently being incorporated into the study (marked with a circle) include Arctic Tundra, AK (ARC); Bonanza Creek, AK (BNZ); Coyote Creek, OR (COY); Fox Creek, OR (FOX); Fernow, WV (FRN); Fushan, Taiwan (FUS); Konza Prairie, KA (KNZ); Loch Vale, NV (LCV); Leading Ridge, PA (LDR); Mai Mai, New Zealand (MAI); McMurdo Dry Valley, Antarctica (MCM); North Temperate Lakes, WI (NTL); Panola, VA (PAN); Reynolds Creek, ID (RCR); Sleepers River, VT (SLP); San Dimas, CA (SND); Station Creek, Australia (STN); Warra, Australia (WAR); and Walnut Gulch, AZ (WLG).

for the other sites shown in Figure 1, and work will shortly begin on developing an ecohydrological classification scheme across this extended range of sites. The project homepage may be found at http://www.fsl.orst.edu/~post/ hydro.

Sites examined thus far display a range of ecologically-important patterns of seasonal streamflow variability driven by climate-vegetation-streamflow interactions (Figure 2). Climatically-imposed seasonal variation in precipitation is amplified by asynchrony between precipitation and evapotranspiration (ET) at Andrews and Caspar Creek, producing highly variable seasonal streamflow patterns. On the other hand, at Coweeta precipitation is uniformly spread throughout the year, and seasonal variation in streamflow is produced by summer ET. At Hubbard Brook, seasonal variation in streamflow is the result of snowpack storage and melt during the spring period of leaflessness, as well as summer ET. At Luquillo, ET is almost constant throughout the year because of evergreen vegetation, and streamflow response thus displays little seasonal variation.

This type of cross-site comparison is useful in identifying the relative strength of climate, vegetation, and landscape controls on streamflow generation by holding some factors constant while examining the variation in other factors. For example, Caspar Creek and Hubbard Brook have approximately the same mean annual precipitation (MAP), but mean annual discharge (MAQ) is much higher at Hubbard Brook (Figure 2). This reflects the higher ET at Caspar Creek due to its relatively warm winter temperatures, whereas subfreezing temperatures and leaflessness at Hubbard Brook conspire to store water in plant-unavailable form (snow) while ET is practically zero. Peak runoff at Hubbard Brook occurs in spring during snowmelt when the deciduous trees have not yet begun transpiring, whereas peak runoff in the temperate rainforest at Andrews and Caspar Creek occurs during winter when unfrozen soils and dormant conifers let the high amounts of precipitation pass through the system. Vegetation induces soil moisture deficits and reduces streamflow at Andrews, Caspar Creek, Coweeta, and Hubbard Brook for predictable periods defined by the phenology of the vegetation and the available soil water, but soil moisture surpluses and deficits are not regulated by these processes at Luquillo (Figure 2). Many other similar comparisons and contrasts are possible.

> *Ecological hydrology as we have defined it also faces major challenges ... Foremost among these is data quality, comparability, and access*

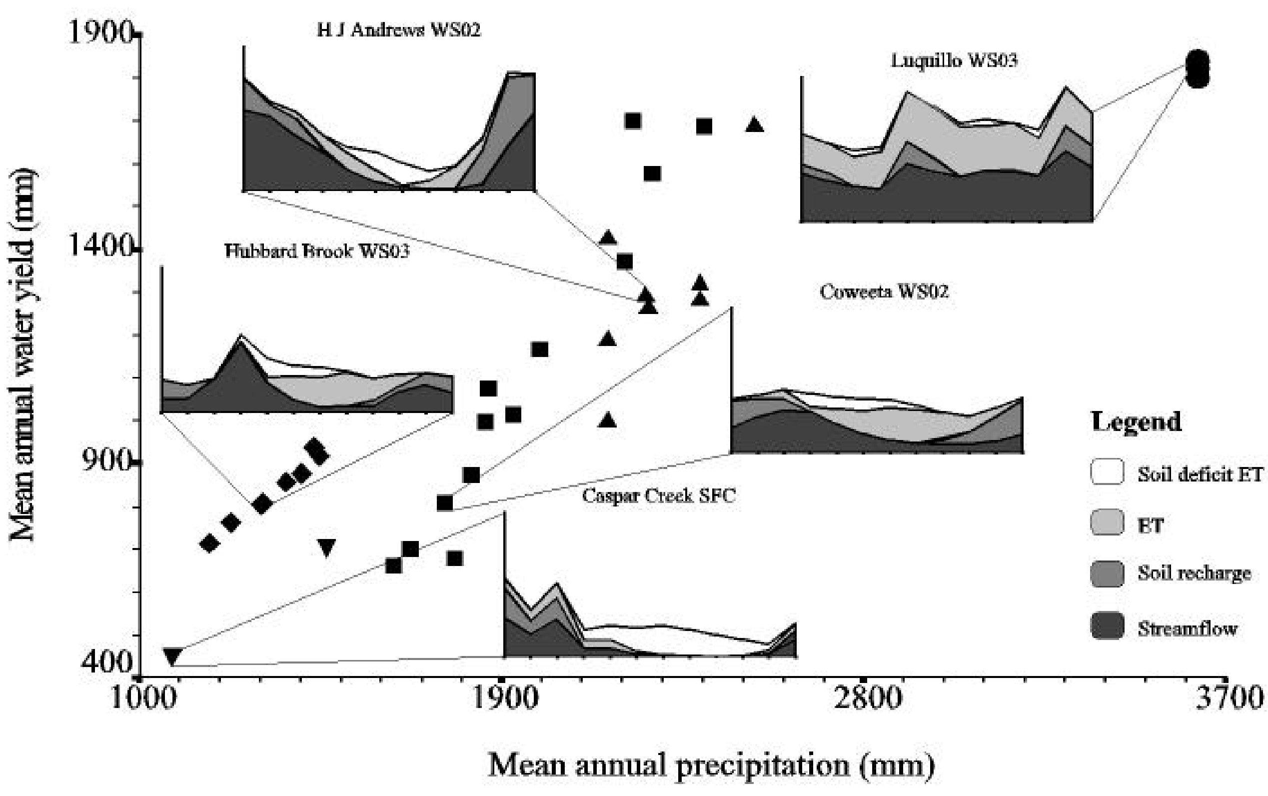



Figure 2. Mean Annual Streamflow Plotted Against Mean Annual Precipitation for Small Experimental Catchments at Five Sites. The distribution of precipitation, streamflow, ET, and soil recharge/deficit throughout the year are shown for one representative catchment at each site. The top of the solid portion represents monthly precipitation. The x-axes range from January to December, and the scale on all five plots is the same, the top of the y-axis being 450 mm.

A workshop held on November 20-21, 1997, and a special session held at the Spring AGU meeting in Boston on May 27, 1998, brought together scientists from the LTER network and USDA Forest Service and Agricultural Research Service experimental watershed study sites to discuss a common framework for comparing climate, hydrology, and vegetation interactions across their widely varying sites. Currently, the controls on hydrologic response are examined on an *ad-hoc* basis, focusing on a particular issue for an individual study. These scientists' interest in a collaborative approach to ecological hydrology reflects, in part, a recognition that their combined long-term datasets have the potential to contribute to issues extending beyond initial treatment effects, to ecosystem analyses and the causes and consequences of vegetation succession, climate, and landuse change.

One commonality emerging from these discussions was the role played by storage at each site. Intersite ecological hydrology comparisons have the potential to reveal the contribution of water storage to daily, seasonal, or inter-annual variability in streamflow. The influence upon streamflow patterns of various forms of water storage – in snow, soil, and forest canopies – varies among sites. Storage is dominant when and where the inputs to that storage are volumetrically and temporally compatible with the volume and rates of discharge from the store. When the temporal distribution or volumetric inputs overwhelm the store, it becomes unimportant. For example, the canopy store at Luquillo is an important process when the inputs of precipitation are relatively small, short-lived, and well-spaced temporally. However, during flood events, the store is overwhelmed by the volume and timing of the inputs, and thus rendered ineffectual. Timing of storage turnover – from daily interception and evaporation of canopy water to seasonal snowmelt and soil moisture drawdown – has critical implications for streamflow, availability of water to vegetation, and key feedbacks to stream ecology by determining the timing of base flow periods when maximum ecological stresses may occur in streams. The degree to which landscapes 'remember' the previous climate is also strongly conditioned by the type of storage (where dominant storages have rapid rates of turnover, little memory may persist, but groundwater dominated systems transmit a water surplus or deficit over periods of years). For example, at Coweeta, with a large volume of soil storage, the effects of a single drought year can be felt for a number of years afterwards. However, the seasonal nature of the snowpack storage at Hubbard Brook means that the effects of a drought are rarely felt even in the following year.

Intersite ecological hydrology comparisons also have the potential to clarify how anthropogenic or natural disturbances produce varying hydrologic responses in different landscapes. Different types of climate-vegetation-streamflow interactions imply that the removal of vegetation will have different, but predictable, impacts on hydrologic response. For example, forest cutting produces increases in streamflow peaks at sites (or during seasons) when transpiration by the undisturbed vegetation accounts for large water losses. Thus, we expect transpiration-related increases in spring and autumn at H.J. Andrews and Caspar Creek, in summer at Coweeta and Hubbard Brook, and all year round at Luquillo. However, forest removal may also produce declines in streamflow at sites (or during seasons) where vegetation modifies precipitation by affecting cloudwater interception or snow accumulation. Examples include interception-related decreases in summer at Caspar Creek, or snow accumulation-related decreases in winter at Hubbard Brook. If consistent relationships between climate, vegetation, landscape attributes and streamflow can be inferred from intersite ecological hydrology comparisons, predictions of the hydrologic response of ungaged catchments may be facilitated.

Ecological hydrology as we have defined it also faces major challenges. Foremost among these is data quality, comparability, and access. The most difficult challenge for ecological hydrology is the lack of hydrologically-relevant data about vegetation, soil, snow, and stream ecology. The importance of such deficiencies depends upon study objectives. For example, critical data are lacking on how vegetation structure affects interception of rain and snow, or how soil water availability and vapor-pressure deficits control transpiration rates for functionally distinct groups of plants. Currently-available vegetation and soil maps are rarely compiled using mapping units that relate to hydrologic function. Many sites also do not have data available in a readily transferable (i.e., computerized) format. To conduct a meaningful ecological hydrology analysis may require re-interpretation of available data, additional mapping, or even detailed field measurements.

Inconsistencies among sites or monitoring periods in the type and quality of precipitation and streamflow data also impose constraints on what we can learn from intersite ecological hydrology analyses. For example, at some sites the raingage network is dense and dispersed throughout the catchment being monitored (Hubbard Brook), while at other sites there may be one raingage per catchment (Coweeta), or a single raingage may be used to determine the inputs for a number of catchments (H.J. Andrews). Similarly, at some sites, the hydrologic data is of high quality, being measured by v-notch weirs (Coweeta, Hubbard, and Brook) while elsewhere, less accurate flumes are used (H.J. Andrews and Caspar Creek), and in some places, no weir or flume is used at all (Luquillo). A major accomplishment of this project will be to collect relevant data from several sites and convert them into consistent formats and units and make them available on the World Wide Web.

Many opportunities remain in ecological hydrology. These initial intersite comparisons were all carried out at an annual or monthly timestep (other ecological hydrology linkages come into focus when data are examined at shorter timescales). A coordinated research program, involving field experiments at plot, small catchment and landscape scales, historical analyses of long-term data, and modeling and simulation, will be required to capture these subtle patterns. Such a research program may also lead to more consistent monitoring of key environmental variables, and promote interactions across sites. The payoff will be an improved understanding of how hydrologic processes both provide the template for ecological systems but are themselves modified by the very ecosystems they support.

ACKNOWLEDGMENTS

This research and the workshop were sponsored by NSF Grant No. DEB-9526987. The assistance of co-workers from the LTER, USFS, and USDA-ARS sites is gratefully acknowledged. Some of the material in this article first appeared in EOS 79 (43):517, 526.

LITERATURE CITED

Bormann, F.H. and G.E. Likens, 1979. Pattern and Process in a Forested Ecosystem. Springer-Verlag, New York, New York.

Hewlett, J.D. and A.R. Hibbert, 1967. Factors Affecting the Response of Small Watersheds to Precipitation in Humid Areas. *In:* International Symposium on Forest Hydrology. Pergamon Press, New York, New York, pp. 275-290.

Likens, G.E. (Editor), 1983. An Ecosystem Approach to Aquatic Ecology. Springer-Verlag, New York, New York.

Likens, G.E., F.H. Bormann, R.S. Pierce, J.S. Eaton, and N.M. Johnson, 1977. Biogeochemistry of a Forested Ecosystem. Springer-Verlag, New York, New York.

Meyer, J. *et al.,* 1993. Stream Research in the Long-Term Ecological Research Network. LTER Publication No. 15, LTER Network Office, Seattle, Washington.

Swank, W.T. and D.A. Crossley, Jr., 1988. Forest Hydrology and Ecology at Coweeta. Springer-Verlag, New York, New York.

AUTHOR LINK

David A. Post
CSIRO Land and Water Davies Laboratory
PMB PO Aitkenvale
Queensland, 4814, Australia
Phone: 61-7-4753-8605
Fax: 61-7-4753-8650

Julia A. Jones
Department of Geosciences
Oregon State University
Corvallis, OR 97331
(541) 737-1224 / Fax: (541) 737-1200

Gordon E. Grant
U.S. Forest Service
Forestry Sciences Laboratory
3200 SW Jefferson Way
Corvallis, OR 97331
(541) 750-7328 / Fax: (541) 750-7329

E-MAIL

David.Post@tvl.clw.csiro.au
jonesj@geo.orst.edu
grant@fsl.orst.edu

**David Post** is a surface water hydrologist, working for CSIRO Land and Water in Townsville, Australia. His research interests include the regionalization of hydrologic response through deriving relationships between hydrologic response and landscape and vegetative controls, and relating the fluxes of water, sediment and nutrients to land cover characteristics. He is currently pursuing these research interests in the Burdekin and Herbert catchments of North Queensland, but retains a research interest in the U.S. Long Term Ecological Research network. He holds a B.S. from the University of Newcastle (Australia), and a Ph.D. in Hydrology from the Australian National University.

**Julia A. Jones** is an Associate Professor, Department of Geosciences, at Oregon State University in Corvallis, Oregon. She is a Principal Investigator in the LTER Program at the H.J. Andrews Experimental Forest.

**Gordon E. Grant** is a Hydrologist/Geomorphologist with the Pacific Northwest Research Station, USDA Forest Service, Corvallis, Oregon. He is a Principal Investigator in the LTER Program at the H.J. Andrews Experimental Forest.

❖ ❖ ❖

## A WORD FROM OUR PRESIDENT . . .

The core of any organization is its staff and AWRA is extremely fortunate to have a team of professionals that are dedicated heart and soul to this organization. They are highly talented, forward thinking, hard working, and (above all) friendly and always eager to help our members and customers. They truly work from the heart, and the respected reputation of AWRA reflects their personal commitment.

At the helm is AWRA's Executive Vice President Ken Reid, whose 19 years of leadership and vision have shaped the staff team and guided our organization through the "uncertain waters" of change, while advancing us forward in a high competitive era.

In recognition of his many outstanding accomplishments, Ken Reid has been selected to receive the highly prestigious "2000 Key Award" from the American Society of Association Executives (ASAE). This award is given by ASAE to chief staff officers "who continually bring credit to the association management profession through their leadership in their own association and their involvement in other voluntary membership organizations." Clearly, Ken is most deserving of his honor. the award will be presented to Ken at the ASAE Annual Meeting in Orlando, Florida, on August 13, 2000. Several AWRA officers and past presidents will be attending the event.

The AWRA Board of Directors is very proud and appreciative of Ken and his contributions to AWRA.

Thank you Ken, and congratulations!!!

Jan Bowers
President

## FUTURE AWRA MEETINGS / 2000

**August 27-30, 2000**
Summer Specialty International Conference
RIPARIAN ECOLOGY AND MANAGEMENT
IN MULTI-LAND USE WATERSHEDS
**Portland, Oregon**

**November 6-9, 2000**
AWRA's ANNUAL WATER RESOURCES CONFERENCE
**Miami, Florida**

**For additional information: info@awra.org**

## PAPERS APPEARING IN THE JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION JUNE 2000 • VOL. 36 • NO. 3

**Dialogue on Water Issues**

- Uncalculated Impacts of Unsustainable Aquifer Yield Including Evidence of Subsurface Interbasin Flow
- Wicked Water Problems: Sociology and Local Water Organizations in Addressing Water Resources Policy
- EPA's Basins Model: Good Science or Serendipitous Modeling?

**Technical Papers**

- Ground Water Drought Management by a Feedforward Control Method
- Comparative Study of Drought Prediction Techniques for Reservoir Operation
- Spatially Distributed Modeling of Stream Flow During Storm Events
- Sizing of Surface Water Runoff Detention Ponds for Water Quality Improvement
- An Empirically-Based Sequential Ground Water Monitoring Network Design Procedure
- Development of a GIS-Based Flood Information System for Floodplain Modeling and Damage Calculation
- DEM Aggregation for Watershed Modeling
- Selection of Appropriate Evaporation Estimation Technique for Continuous Modeling
- Effect of Water Quality Standards on Farm Income, Risk, and NPS Pollution
- Artificial Neural Networks for Subsurface Drainage and Subirrigation Systems in Ontario, Canada
- Fog and Acidification Impacts on Ion Budgets of Basins in Nova Scotia, Canada
- Channel Stability Downstream From a Dam Assessed Using Aerial Photographs and Stream-Gage Information
- Distribution of Sediment Phosphorus Pools and Fluxes in Relation to Alum Treatment

**Addendum**

- Climate Change Sensitivity Analysis for Two California Watersheds: Addendum to Downscaled Climate and Streamflow Study of the Southwestern United States

**JAWRA**
**Journal of the American Water Resources Association**

## REQUEST FOR PROPOSAL FOR EDITOR OF THE JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION

### Deadline: September 30, 2000

The American Water Resources Association is requesting proposals for a new Editor for its flagship publication – Journal of the American Water Resources Association (JAWRA). JAWRA is an interdisciplinary journal focusing on applied aspects of water resources science and management. It is published six times annually and publishes approximately 100 papers per year. Each edition includes book reviews and dialogue on pressing water resources issues.

**The term for editorship is four years and will begin no later than December 31, 2001.**Candidates will be judged with regard to their qualifications in the water resources management and research field and their demonstrated abilities to fulfill the responsibilities of editorship of a major professional journal. We are particularly interested in candidates who have a broad understanding and appreciation of water resources management, science, and policy issues.

The editor's responsibilities include:

- Working with AWRA staff to ensure the timely and quality publication of JAWRA.
- Actively soliciting high quality manuscripts from multidisciplinary fields related to water resources management by reaching out to highly regarded professionals and researchers.
- Attending AWRA and other symposia and conferences and utilizing the network of water resources professionals to solicit potential manuscripts and reviewers.
- Selecting Associate Editors and working with them to develop a network of reviewers and to select appropriate reviewers of manuscripts.
- Making final decisions on the publication of manuscripts.
- Maintaining a procedure for tracking manuscripts from receipt through the review and revision processes to final publication.
- Developing and maintaining a system of on-line editing of manuscripts to streamline the production process.
- Managing and reporting on budget and staff for JAWRA activities.
- Actively pursuing ideas to improve the quality, content, and presentation of JAWRA; improving its attractiveness and service to the water resources professional community; and developing new sections or special editions of the journal when appropriate.

Proposals should be a maximum of four pages, not including appended material, and are due at AWRA headquarters no later than September 30, 2000. AWRA will announce its selection by November 15, 2000. The proposal should include:

- The academic, editorial, and professional qualifications of the candidate.
- A plan for fulfilling each of the responsibilities listed above and any additional innovative ideas.
- A proposed budget for support of editorial activities, including contributions from the candidate's institution or employer. (Budget items may include salary support for the Editor, secretarial support, communications, travel, supplies, and overhead costs.)

Proposals should be sent to:

JAWRA Editorial Search
American Water Resources Association
4 West Federal Street, P.O. Box 1626
Middleburg, VA 20118-1626.

Inquiries for additional information should be directed to Dr. Stephan J. Nix; Phone: 520/523-4339, Fax: 520/523-2300, e-mail: Stephan.Nix@nau.edu.

# ▲ Heads Up! . . . Compiled by Jeff Edgens

TMDL UPDATE

The TMDL front is moving rapidly and has caught significant attention among forestry and agriculture interests. Few parties seem to support the rules package. Over the last few months members of Congress have introduced legislation to either exempt silviculture from the rules or in some other manner slow down the TMDL program.

Initial concerns regarding the rules package of last fall include EPAs re-classification of silviculture from a nonpoint source to a point source. Other items in the preliminary rules package included offsets, and deadlines for achieving water quality standards.

Environmental groups sent a letter to Carol Browner asking her to withdraw the EPA rules package. Their letter mentions the attention TMDL rules have received and Agency changes would only weaken the proposed rules. Weakened rules are just as bad as no rules, they claim.

As of this writing EPA has removed the offset requirements from the draft rules and any reference to achieving water quality standards to a certain time frame. The re-classification of nonpoint sources as point sources is being removed as well. EPA expects to address silviculture in the fall, probably with another notice of proposed rulemaking.

However, members of Congress are seeking a delay in rule implementation until a National Academy of Sciences report on the costs of TMDL implementation is completed in 18 months. Some members of Congress have vowed to kill the regulations outright, through riders to the appropriations process. What finally happens is anybody's guess. We will keep you posted.

FARMERS APPEAL TMDL RULING

On March 30, Judge William Alsup ruled for EPA's motion of summary judgment in a landmark legal case in which Judge Alsup declared TMDLs appropriate for nonpoint source controls.

A California farm family had claimed that EPA had overstepped its authority in listing the Garcia River as impaired due to sediment from nonpoint sources. The family argued that the Clean Water Act TMDL requirements did not apply to nonpoint sources. Similar reasoning was applied in Oregon Natural Desert Association vs Dombeck when the judge in that case declared the Act silent as to "nonpoint source discharge."

Judge Alsup ruled that TMDL requirements to states for nonpoint sources are within EPA's purview, but he stopped short of requiring TMDLs. In essence, states should consider TMDLs for nonpoint as advisory only.

Farm interests have appealed the lower court's decision.

ADMINISTRATION PROPOSES MARINE PROTECTED AREAS (MPAS)

[Executive Order 13158 creates Marine Protected Areas (MPAs) through "science based regulations" to protect marine environments, including the Great Lakes]

Lead agencies include the Department of Commerce and the Department of Interior to consult with other federal agencies for the purpose of creating a national system of MPAs.

The idea is to set water quality standards for each coastal environment that adequately safeguards marine ecosystems like coral reefs. The current system applies general conditions for waters uniformly in coastal areas.

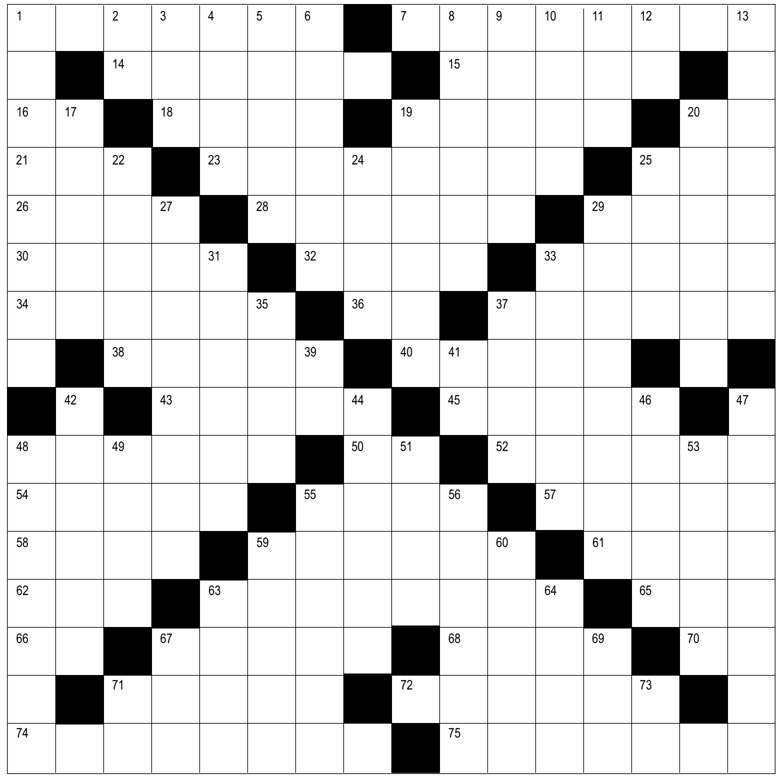
First steps are to determine which discharges to regulate and how they impact the marine environment. Part of this also includes a "classification system" to define various coastal areas. Tailored regulations for appropriate waterbodies and pollutants appear to be the direction the agency wants to go.

But industry is concerned with the Great Lakes designation as a "marine environment." Business, industry, and the Great Lakes states are responding to the Great Lakes Initiative which already addresses some water quality problems. Moreover EPA attempted a policy a few years ago to regulate nonpoint sources of pollution through a similar GLI like tool, it failed to materialize in large measure due to the pre-existing GLI requirements.

(Please E-Mail your submissions or suggestions of timely water quality efforts in your state or industry to me at jedgens@ca.uky.edu.)

❖ ❖ ❖

## ▲ Water Resources Puzzler (answers on pg. 50)



ACROSS
1 river in Georgia
7 NHL player from New York
14 a nutritious yeast
15 followed by guard or filter
16 an NCO
18 arm or leg
19 underwater echolocation
20 between McKinley and Taft
21 aunt or uncle (abbr.)
23 water pipe characteristic
25 _______ Lanka
26 plans for the over-65 crowd
28 tributary to the Black Sea
29 followed by tire or top
30 _______-store Indian
32 positive votes
33 three-time AL batting champ
34 made amends
36 5/8 of a mile
37 island of New York
38 river in Illinois
40 1948 Nobel Prize winner
43 distinctive period of time
45 hello in the 50th state
48 not happier
50 Sumerian god of heaven
52 impulsive thief (slang)
54 a plant's spine
55 boast
57 having ears
58 a printing process, for short
59 a tusked mammal
61 followed by sheet or head
62 a poet's before
63 river in Maryland
65 zero
66 associate degree in education
67 Egyptian leader
68 acting too hastily
70 Beaverdam River state
71 pertaining to bees
72 unproductive people
74 river in Georgia
75 light rainfalls

DOWN
1 river in California
2 symbol for astatine
3 a politician?
4 dry
5 damp
6 river in New York
8 Randolph and namesakes
9 a person who avoids others
10 winglike
11 neither's partner
12 a physician (abbr.)
13 river in New Jersey
17 a Boy Scout badge
19 a famous street?
20 popular pasttime
22 Nigerian seaport
24 spiritless
25 a long fissure
27 river in Arizona
29 lake in Minnesota
31 to open again
33 Peter or Annette
35 followed by handle or prize
37 a lustrous fiber
39 Neuse River state
41 Red River state
42 city in Pakistan
44 a prostitute
46 part of a dam's stilling basin
47 users of HEC-1 or TR-20
48 watercourses
49 bestow excessive love
51 undercover cop
53 lukewarm
55 followed by republic or split
56 backcourt players
59 chief pagan god
60 follows decimal or union
63 river in Germany
64 river in Belgium
67 a mineral spring
69 Charlemagne's domain (abbr.)
71 month of the Jewish calendar
73 system of units (abbr.)

❖ ❖ ❖

# ▲ Water Resources Continuing Education Opportunities

**MEETINGS, WORKSHOPS, SHORT COURSES**

**AUGUST 2000**

6-12/Intercol VI-Global Watersheds at the Millennium. Quebec City, Canada. **Contact** Clayton Rubec, Canadian Wildlife Serv., Environment Canada, Ottawa, Ontario, Canada K1A 0H3 (819/953-0485; fax: 819/994-4445; e-m: clay.rubec@ec.gc.ga)

7-10/Applied Environmental Statistics. Sacramento, CA. **Contact** Intern'l. Groundwater Modeling Ctr., Colorado School of Mines, Golden, CO 80401-1887 (303/273-3103; fax: 303/384-2037; e-m: igwmc@mines.edu; http://www.mines.edu/igwmc/)

7-11/Process Based Channel Design: Innovative Approaches for Repairing Disturbed Stream Environments (Short Course). Milwaukee, WI. **Contact** Inter-Fluve, Inc., 25 N. Willson, Ste. 5, Bozeman, MT 59715 (406/586-6926; e-m: shortcourse@interfluve.com; www.interfluve.com)

7-11/National Beach Preservation Conf. Kannapali, Maui, HI. **Contact** Rob Mullane (808/984-3254; fax: 808/242-8733; e-m: mullane@hiwaii.edu)

14-17/Water Security of the 21st Century – 10th Stockholm Water Sym. Stockholm, Sweden. **Contact** Stockholm Convention Bureau, "SWS 2000," PO Box 6911, SE-102 39 Stockholm, SWEDEN (+46 8 54 65 15 99)

14-24/Dam Safety, Operation & Maintenance (Technical Seminar & Study Tour). Denver, CO. **Contact** International Affairs Team, D-1520, U.S. Bureau of Reclamation, P.O. Box 25007, Denver, CO 80225 (303/445-2127; fax: 303/445-6322; e-m: lprincipe @do.usbr.gov)

17-21/5th Intn'l. Sym. on Environ. Geotechnology and Global Sustainable Devel. Belo Horizonte, Minas Gerais, Brazil. **Contact** Prof. Terezinha Galvao, (+55 31 2381742; fax: +55 31 2381793; e-m: cassia@etg.ufmg.br; www.5iseggsd.eng.ufmg.br)

20-24/American Fisheries Soc. 130th Ann. Meeting. St. Louis, MO. **Contact** Julie E. Claussen (217/244-5113; e-m: jclaussen@fisheries.org)

**27-30/Riparian Ecology & Mgmt. in Multi-Land Use Watersheds. Portland, OR. Contact AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; fax: (540/687-8395; e-m: info@awra. org)**

**SEPTEMBER 2000**

5-8/Intn'l. Workshop on Develop. & Mgmt. of Flood Plains & Wetlands. Beijing, China. **Contact** Mr. Jiang Chao, IWFW 2000, IRTCes, P.O. Box 366, Beijing, China (+86-10-68413372; fax: +86-10-68411174; e-m: irtces@public.east.cn.net)

12-13/Water Reuse Association - Symp. XV. Napa, CA. **Contact** Watereuse Assoc., Attn: L. Wire, 915 L Street, Ste. 1000, Sacramento, CA 95814 (916/442-2746; fax: 916/442-0382; e-m: law@ngke.com; http://www.watereuse.org)

13-15/Fluvial Geomorphology & Floodplain Mgmt. Sacramento, CA. **Contact** Laura Hromadka, Conf. Coordinator, Floodplain Mgmt. Assoc., P.O. Box 2972, Mission Viejo, CA 92692 (949/766-8112; fax: 949/459-8364; e-m: fmalaura@pacbell.net)

18-20/Coastal Environment 2000 – 3rd Intn'l. Conf. Las Palmas de Gran Canaria, Spain. **Contact**: Sally Walsh, Conf. Secretariat, Oil Spill 2000, Wessex Inst. of Tech., Ashurst Lodge, Ashurst, Southampton SO40 7AA, UK [+44(0)238 029 3223; fax: +44(0) 238 029-2853]

20-22/Oil Spill 2000 – 2nd Intn'l. Conf. Las Palmas de Gran Canaria, Spain. **Contact** Sally Walsh, Conf. Secretariat, Oil Spill 2000, Wessex Inst. of Tech., Ashurst Lodge, Ashurst, Southampton SO40 7AA, UK [+44(0)238 029 3223; fax: +44(0) 238 029-2853]

26-29/Dam Safety 2000: Association of State Dam Safety Officials Annual Conference. Providence, RI. **Contact** ASDSO, 450 Old Vine St., Second Floor, Lexington, KY 40507 (606/257-5140; e-m: info@damsafety.org; http://members.aol.com. damsafety/homepage.htm)

**OCTOBER 2000**

9-11/The Eighth Intern'l. Sym. on Animal, Agricultural, & Food Processing Wastes (ISAAFPW 2000). Des Moines, IA. **Contact** (800/371-2723; e-m: http://asae.org)

9-13/Process Based Channel Design: Innovative Approaches for Repairing Disturbed Stream Environments (Short Course). Seattle, WA. **Contact** Inter-Fluve, Inc., 25 N. Willson, Ste. 5, Bozeman, MT 59715 (406/586-6926; e-m: shortcourse@interfluve.com; www.interfluve.com)

11-13/Risk Analysis 2000. Bologna, Italy. **Contact** Conf. Secretary Susan Hanley (e-m: shanley@wessex.ac.uk; http://www.wessex.ac.uk/conferences/2000/risk2000/)

13-15/Fluvial Geomorphology & Floodplain Mgmt. Sacramento, CA. **Contact** D. Kennedy, Tech. Prog. Chair, The Spink Corp., 2590 Venture Oaks Way, Sacramento, CA 95833 (916/925-5550; fax: 916/921-9274; e-m: dkennedy@spink.com; or Laura Hromadka, Conf. Coordinator, Floodplain Mgmt. Asso., P.O. Box 2972, Mission Viejo, CA 92692 (949/766-8112; fax: 949/459-8364; e-m: fmalaura@pacbell.net)

23-26/Annual Meeting of the National Association of Flood & Stormwater Management Agencies. San Diego, CA. **Contact** NAFSMA (http://nafsma.org)

**NOVEMBER 2000**

5-8/AIH Annual Meeting-Atmospheric, Surface, & Subsurface Hydrology & Interactions. Research Triangle Park, NC. **Contact** AIH, 2499 Rice St., Ste. 135, St. Paul, MN 55113 (651/484-8169; fax: 651/484-8357; e-m: AIHydro@aol.com)

**6-9/AWRA's Annual Water Resources Conference. Miami, FL. Contact AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; fax: 540/687-8395; e-m: info@awra.org)**

8-10/Water Research Sym. 2000. Blacksburg, VA. **Contact** T. Yunos, VWRRC, 10 Sandy Hall, Virginia Tech, Blacksburg, VA 24061 (fax: 540/231-6673; e-m: tyounos@vt.edu; http://www.vwrrc.vt.edu)

8-10/Facilitating and Mediating Effective Environmental Agreements (Short Course). Berkeley, CA. **Contact** CONCUR, Inc., (510/649-8008; www.concurinc.com)

13-15/Asking the Right Questions – Evaluating the Impact of Groundwater Education – 2000 Groundwater Found. Fall Conf. Nebraska City, NE. **Contact** The Groundwater Foundation, P.O. Box 22558, Lincoln, NE 68542-2558 (fax: 402/434-2742; e-m: info@groundwater.org)

14-16/Fourth Decennial National Irrigation Sym. Phoenix, AZ. **Contact** (800/371-2723; e-m: http://asae.org)

20-23/Hydro 2000, Third Intern'l. Hydrolgy and Water Resources Sym. Perth, Australia. **Contact** (conwes@congresswest.com.au; http://www.ieaust.org.au/hydro2000)

27-30/Managing Watersheds in the New Century: Eighth Biennial Watershed Mgmt. Conf. Monterey, CA. **Contact** Rick Kattelmann, Watershed Mgmt. Council (760/935-4903; fax: 760/935-4867; e-m: rick@icess.ucsb.edu or sari@sisqtel.net; http:// watershed.org/wmc)

**DECEMBER 2000**

3-6/2000 Midwest Fish & Wildlife Conf. (62nd Annual), Minneapolis, MN **Contact** (http://midwest2000.fws.gov)

**JANUARY 2001**

3-5/Second Intern'l. Sym. on Preferential Flow – Water Movement & Chemical Transport in the Environment. Honolulu, HI. **Contact** (800/371-2723; e-m: http://asae.org)

15-18/Conf. on Tailings & Mine Waste '01. Colorado State Univ., Ft. Collins, CO. **Contact** Linda Hinshaw, Dept. of Civil Engr., Colorado State Univ., Ft. Collins, CO 80523-1372 (970/491-6081; fax: 970/491-3584; e-m: lhinshaw@engr.colostate.edu)

25-26/Sym. on Spatial Methods for Solutions of Environ. & Hydrol. Problems. Reno, NV. **Contact** Dr. A. Ivan Johnson, 7474 Upham Ct., Arvada, CO 80003-2758 (303/425-5610; fax: 303/425-5655)

**FEBRUARY 2001**

5-9/Intern'l. Erosion Control Association – 32nd Annual Conf. Las Vegas, NV. **Contact** IECA, P.O. 774904, Steamboat Springs, CO 80477-4904 (970/879-3010; fax: 970/879-8563; ecinfo@ieca.org; http://www.ieca.org

**MARCH 2001**

11-14/American Water Works Association – Infrastructure Conf. Orlando, FL. **Contact** AWWA, 6666 W. Quincy Ave., Denver, CO 80235

**APRIL 2001**

**30-May 2/AWRA's Spring Specialty Conf. San Antonio, TX. Contact AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; fax: 540/687-8395; e-m: info@awra.org)**

**MAY 2001**

31-June 2/Water & Rural History. Reno, NV. **Contact** W.D. Rowley, History Dept., Univ. of NV, Reno, NV 89557 (e-m: rowley@scs.unr.edu)

**JUNE 2001**

3-8/Association of State Floodplain Managers – 25th Annual Conf. Charlotte, N.C. **Contact** asfpm, 2809 Fish Hatchery Rd., Ste. 204, Madison, WI 53713-3120 (608/274-0123; fax: 608/274-0696; e-m: asfpm@floods,org; http://www.floods.org)

10-15/5th Intern'l. Conf. – Diffuse/Nonpoint Pollution & Watershed Mgmt. Milwaukee, WI. **Contact** IWA Conf. c/o Inst. for Urban Environmental Risk Mgmt., Marquette Univ., Milwaukee, WI 53201-1881 (fax: 414/288-7521)

25-27/3rd Intern'l. Conf. – Future Groundwater Resources at Risk. Lisbon, Portugal. **Contact** L. Ribeiro, Centro De Valoizacao de Recursos Minerais DO I.S.T., I.S.T. Av. Rovisco Pais 1096, Lisboa, Codex, Portugal (351-1-841 72 47; fax: 351-1-841 74 42)

**26-July 1/AWRA's Summer Specialty Conf. Snowbird, UT. Contact AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; fax: 540/687-8395; e-m: info@awra.org)**

27-30/Transbasin Water Transfers – U.S. Committee on Irrigation & Drainage. Denver, CO. **Contact** Larry D. Stephens (303/628-5430; fax: 303/628-5431; e-m: stephens@uscid.org)

**JULY 2001**

30-Aug. 2/Managing River Flows for Biodiversity: A Conf. on Science, Policy, & Conservation Action. Ft. Collins, CO. **Contact** Nicole Silk (e-m: nsilk@tnc.org; www.freshwaters.org)

18-27/Intern'l. Association of Hydrological Sciences – 6th Scientific Assembly. Maastricht, The Netherlands. **Contact** IAHS Maastricht 2001, c/o Conference Agency Limburg, P.O. Box 1402, 6201 BK Maastricht, The Netherlands (43 3619192; fax: +31 43 3619020; e-m: cal.conferenceagency@wxs.nl)

**NOVEMBER 2001**

**12-15/AWRA's Annual Water Resources Conference. Albuquerque, NM. Contact AWRA, 4 West Federal St., P.O. Box 1626, Middleburg, VA 20118-1626 (540/687-8390; fax: 540/687-8395; e-m: info@awra.org)**

## CALLS FOR ABSTRACTS

**AUGUST 1, 2000 (Abstracts Due)**

Transbasin Water Transfers – U.S. Committee on Irrigation and Drainage. June 27-30, 2001. Denver, CO. **Contact** Larry D. Stephens (303/628-5430; fax: 303/628-5431; e-m: stephens@uscid.org)

**AUGUST 18, 2000 (Abstracts Due)**

American Water Works Association – Infrastructure Conf. March 11-14, 2001. Orlando, FL. **Contact** AWWA, 6666 W. Quincy Ave., Denver, CO 80235

**SEPTEMBER 30, 2000 (Abstracts Due)**

5th Intern'l. Conf. – Diffuse/Nonpoint Pollution and Watershed Mgmt. June 10-15, 2001. Milwaukee, WI. **Contact** IWA Conference, c/o Inst. for Urban Environmental Risk Mgmt., Marquette Univ., Milwaukee, WI 53201-1881 (414/288-7521; e-m: mburkart@nstl.gov; http://www.mu.edu/environment/iwa-page.htm)

**DECEMBER 31, 2000 (Abstracts Due)**

Managing River Flows for Biodiversity: A Conference on Science, Policy, & Conservation Action. July 30-August 2, 2001. Colorado State Univ., Ft. Collins, CO. **Contact** Nicole Silk (e-m: nsilk@tnc.org; www.freshwaters.org)

❖ ❖ ❖

# ▲ Feedback

**Agricultural Water Policy in the New Millennium: Working Outside the Fence – May 2000 (Vol. 2, No. 3)**

Just finished reading Akobundu and Riggs' recent article in *IMPACT* on "Pervasive Permitting: The EPA's Proposed TMDl Rules." It was quite interesting and informative. The authors are to be congratulated on a good job.

*Robert M. Hordon*
Rutgers University, Dept. of Geography
Piscataway, NJ

The article on "Agriculture and Water Markets in the New Millennium" by Clay J. Landry from the May issue of *IMPACT* was excellent. I am trying to get info about the timeframe for submitting "Feedback" articles in time for the next *IMPACT* issue. Can you provide this information?

*Sydney Bacchus*
University of Georgia
Athens, GA

*Feedback depends on the extent of comments (letter or article). In either case we attempt to get feedback into the very next issue. Our next issue deadline will be August 10 for the September release. I hope this helps. Please let me know what you have in mind (letter or article) and we can tell you what the space limitations are for "Feedback." Letters will probably have a better chance of being published.*

Jeff Edgens, Associate Editor

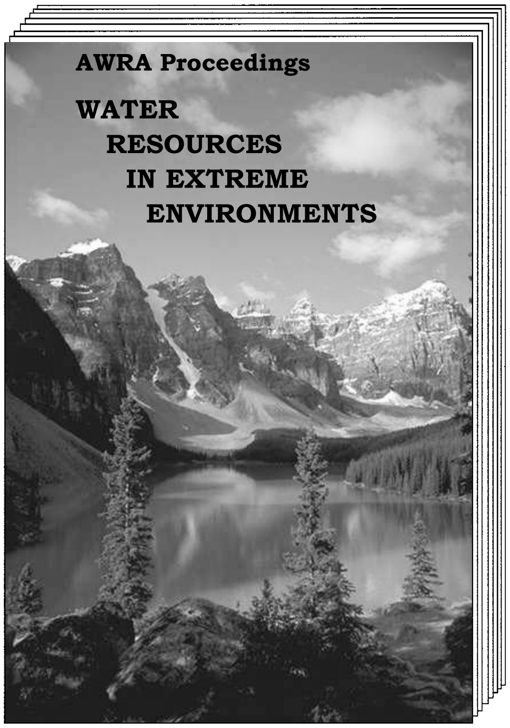
The May issue of *IMPACT* has just reached me. I'd like to congratulate you (and the contributors) on another useful edition. Over the last year or so, the focus in each issue by practitioners on a particular topic has been both interesting and useful. Now that I am working outside the U.S., away from my old day-to-day contacts, I find the issues described in *IMPACT* very useful.

*William L. Magette*
College Lecturer, University College-Dublin
Agricultural and Food Engineering Department
Dublin, Ireland

I appreciate all that you do to make *IMPACT* valuable reading. This magazine plays an important niche role. The May 2000 issue was most informative. I particularly appreciated Elizabeth Fowler's article on "Landowner Innovation and Market Opportunities are the Best Avenues for Water Conservation: The Lundberg Family Farms." Kudos.

*Stephen J. Burges*
Professor of Civil and Environmental Engineering
University of Washington-Seattle
Seattle, WA

❖ ❖ ❖




The expanding world population continues to stress available freshwater resources. Most of the world's population is concentrated in areas of the world with prime environments, and freshwater resources in these areas may already be – or may soon become – inadequate to meet the demand for water. When this happens in a particular area, water must be imported from other areas or a dispersal of the population of the area will occur. Source areas of additional freshwater are often extreme environments such as mountains, plateaus, and polar regions. Recognizing that extreme environments are ever more important sources of freshwater and that additional hydrologic research and data collection are needed in these areas, the American Water Resources Association sponsored a Spring Specialty Conference on "Water Resources in Extreme Environments," May 1-3, 2000, in Anchorage, Alaska.

These Proceedings brings together papers and posters that were presented at the Conference. The papers are organized under the following categories: • Spatial and Temporal Precipitation Processes, • Catchment Hydrologic Processes, • Runoff Processes, • Water Management, • Subsurface Hydrologic Processes, • Surface/Subsurface Contaminant Processes, • Biogeochemical Processes, • Channel Hydraulics, • Water Quality and Habitat, • Hydrologic Modeling With Atmospheric Forcing, • Modeling Hydrologic Processes of Global Significance, • Weather/Climate Modeling, and • Climate Trends and Impacts on Hydrology. The information contained in these Proceedings will help to advance understanding of water resources research and management issues in extreme environments.

**• 2000 • 56 Papers • 338 Pages • Soft Cover**

**• $30.00 / AWRA Member $37.50 / Non-Member**

**ISBN 1-882132-50-5**

**COMPLETE ORDER BLANK AND MAIL DIRECTLY TO:**
AMERICAN WATER RESOURCES ASSOCIATION • 4 West Federal St. • P.O. Box 1626 • Middleburg, VA 20118-1626
Telephone: (540) 687-8390 / Fax: (540) 687-8395 / E-Mail: info@awra.org

**AWRA Order Form**

| | No. | | Unit Cost | | | Total Cost | |
|---|---|---|---|---|---|---|---|
| COPIES @ $30.00/EACH (AWRA MEMBER DISCOUNT PRICE) | _____ | X | $30.00 | = | | _____ | |
| COPIES @ $37.50/EACH (NON-MEMBER PRICE) | _____ | X | $37.50 | = | | _____ | |
| POSTAGE & HANDLING (P/H) – ADD $6.00/EA BOOK (MEMBER /NON-MEMBER) | _____ | X | $ 6.00 | = | (+) | _____ | (P/H) |
| P/H FOREIGN AIRMAIL OPTION–ADD $10/EA Book (Mexico & Canada) /$25/EA Book (All Others) | _____ | X | $ . | = | (+) | _____ | (AIR MAIL) |
| SUBTOTAL | | | | = | | _____ | |
| VIRGINIA RESIDENTS ADD 4.5% SALES TAX ON "SUBTOTAL" | | | | = | | _____ | |
| [WATER RESOURCES IN EXTREME ENVIRONMENTS (ANCHORAGE) – TPS # 00-1] / **TOTAL ENCLOSED** | | | | = | | _____ | |

**Limited Supply / Order Today!**

**SHIP TO ADDRESS: (NO P.O. BOXES PLEASE)**

NAME: ______________________ COMPANY NAME: ______________________

ADDRESS: ______________________

CITY: ____________ STATE: ________ ZIP+4: ________ COUNTRY: ________

IS THIS ADDRESS YOUR ❍ HOME OR ❍ OFFICE ? AWRA I.D. NO.: ________

**PAYMENT MUST ACCOMPANY ORDER. PAYMENT MAY BE MADE BY CHECK (in U.S. dollars drawn on a U.S. bank), OR ONE OF THE FOLLOWING CREDIT CARDS:**
**(PLEASE CHECK ONE) ❍ VISA ❍ MASTERCARD ❍ DINERS CLUB ❍ AMERICAN EXPRESS ❍ DISCOVER**

CARDHOLDER'S NAME: ______________________

CARD NO.: ______________________ EXPIRATION DATE: ________

TELEPHONE NO. – OFFICE: ______________________ HOME: ______________________

CARDHOLDER SIGNATURE (REQUIRED): ______________________

**ALL SALES FINAL**

BULK ORDER PRICES AVAILABLE UPON REQUEST. NO DISCOUNT TO BOOK DEALERS. ORDERS WITHIN THE CONTINENTAL UNITED STATES MAY BE SHIPPED VIA UPS AND CANNOT BE DELIVERED TO P.O. BOXES.

## AWRA MEMBERSHIP APPLICATION – 2000

**American Water Resources Association**
**4 West Federal St. • P.O. Box 1626 • Middleburg, VA 20118-1626**
**(540) 687-8390 • Fax: (540) 687-8395 • E-Mail: info@awra.org**

➤ COMPLETE ALL SECTIONS (PLEASE PRINT)

LAST NAME FIRST MIDDLE INITIAL

TITLE

COMPANY NAME

MAILING ADDRESS

CITY STATE ZIP+4 COUNTRY

IS THIS YOUR ❑ HOME OR ❑ BUSINESS ADDRESS?

PHONE NUMBER FAX NUMBER

E-MAIL ADDRESS

RECOMMENDED BY (NAME) AWRA MEMBERSHIP NO.

➤ STUDENT MEMBERS MUST BE FULL-TIME AND THE APPLICATION MUST BE ENDORSED BY A FACULTY MEMBER.

PRINT NAME ____________________ SIGNATURE ____________________

ANTICIPATED GRADUATION DATE (MONTH/YEAR): ____________________

➤ KEY FOR MEMBERSHIP CATEGORIES:

JAWRA – JOURNAL OF THE AWRA (BI-MONTHLY JOURNAL)
IMPACT – IMPACT (BI-MONTHLY MAGAZINE)
PROC. – 1 COPY OF AWRA'S ANNUAL SYMPOSIUM PROCEEDINGS

ENCLOSED IS PAYMENT FOR MEMBERSHIP (PLEASE CHECK ONE)
❑ FULLYEAR ❑ HALFYEAR

- ❑ REGULAR MEMBER (JAWRA & IMPACT)............................................$120.00
- ❑ STUDENT MEMBER (IMPACT) FULL YEAR ONLY .......................................$25.00
- ❑ INSTITUTIONAL MEMBER (JAWRA, IMPACT, & PROC.)............................$225.00
- ❑ CORPORATE MEMBER (JAWRA, IMPACT, & PROC.)...............................$325.00
- ❑ AWRA NETWORKING DIRECTORY (MEMBERSHIP LISTING) .......................$5.00
- ❑ MEMBERSHIP CERTIFICATE ..................................................................$6.00

➤ FOREIGN AIRMAIL OPTIONS: PLEASE CONTACT AWRA FOR PRICING.

➤ PLEASE NOTE

- MEMBERSHIP IS BASED ON A CALENDAR-YEAR; AFTER JULY 1ST REGULAR, INSTITUTIONAL, OR CORPORATE MEMBERS MAY ELECT A 6-MONTH MEMBERSHIP FOR ONE-HALF OF THE ANNUAL DUES.
- STUDENTS DO NOT QUALIFY FOR HALF-YEAR MEMBERSHIP.
- REMITTANCE MUST BE MADE IN U.S. DOLLARS DRAWN ON A U.S. BANK.

➤ PAYMENT MUST ACCOMPANY APPLICATION

PAYMENT MUST BE MADE BY CHECK OR ONE OFTHE FOLLOWING CREDIT CARDS:
❑ VISA ❑ MASTERCARD ❑ DINERS CLUB ❑ AMEX ❑ DISCOVER

CARDHOLDER'S NAME ____________________

CARD NUMBER ____________________ EXPIRATION DATE ____________

SIGNATURE (REQUIRED) ____________________

MAIL THIS FORM TO AWRA, 4 WEST FEDERAL ST., P.O. BOX 1626 MIDDLEBURG, VA 20118-1626

**For Fastest Service**

FAX THIS FORM (CREDIT CARD OR P.O. ORDERS ONLY) TO (540) 687-8395

QUESTIONS? . . . CALL AWRA HQ AT (540) 687-8390 OR E-MAIL AT INFO@AWRA.ORG

## DEMOGRAPHIC CODES

(PLEASE LIMIT YOUR CHOICE TO ONE IN EACH CATEGORY)

### JOB TITLE CODES

| | |
|---|---|
| JT1 | Management (Pres.,VP, Div. Head, Sect.Head, Manager, Chief Engineer) |
| JT2 | Engineering (non-mgmt.; i.e., civil,mechanical, planning, systems designer) |
| JT3 | Scientific (non-mgmt.; i.e., chemist, biologist, hydrologist, analyst, geologist, hydrogeologist) |
| JT4 | Marketing/Sales (non-mgmt.) |
| JT5 | Faculty |
| JT6 | Student |
| JT7 | Attorney |
| JT8 | Retired |
| JT9 | Computer Scientist (GIS, modeling,data mgmt.,etc.) |
| JT10 | Elected/Appointed Official |
| JT11 | Volunteer/Interested Citizen |
| JT12 | Non-Profit |
| JT13 | Other ____________________ |

### EMPLOYER CODES

| | | | |
|---|---|---|---|
| CF | Consulting Firm | IN | Industry |
| EI | Educational Institution (faculty/staff) | LF | Law Firm |
| | | FG | Federal Government |
| ES | Educational Institution (student) | RE | Retired |
| | | NP | Non-Profit Organization |
| LR | Local/Regional Gov't. Agency | OT | Other ____________ |
| SI | State/Interstate Gov't. Agency | | |

### WATER RESOURCES DISCIPLINE CODES

| | | | |
|---|---|---|---|
| AG | Agronomy | HY | Hydrology |
| BI | Biology | JR | Journalism |
| CH | Chemistry | LA | Law |
| EC | Economics | LM | Limnology |
| ED | Education | OE | Oceanography |
| EG | Engineering | PH | Physics |
| FO | Forestry | PS | Political Science |
| GR | Geography | PB | Public Health |
| GE | Geology | SO | Soil Science |
| GI | Geographic Information Systems | OT | Other ____________ |

### EDUCATION CODES

| | | | |
|---|---|---|---|
| HS | High School | MS | Master of Science |
| AA | Associates | JD | Juris Doctor |
| BA | Bachelor of Arts | PhD | Doctorate |
| BS | Bachelor of Science | OT | Other ____________ |
| MA | Master of Arts | | |

PLEASE NOTE YOUR SELECTED CODE NUMBERS FROM ABOVE

JOB TITLE CODE ............................................... [ ]
EMPLOYER CODE ............................................... [ ]
WATER RESOURCES DISCIPLINE CODE ..................... [ ]
EDUCATION CODE ............................................ [ ]

# ▲ Future Issues of IMPACT

**SEPTEMBER 2000**

**EMERGING TRENDS IN TECHNOLOGY IN WATER RESOURCES**

RICHARD H. MCCUEN, ASSOCIATE EDITOR / E-MAIL: rhmccuen@eng.umd.edu

**NOVEMBER 2000**

**DIRECTIONS IN THE DEVELOPMENT OF THE WATERSHED TOOLKIT**

JEFFERSON G. EDGENS, ASSOCIATE EDITOR / E-MAIL: jedgens@ca.uky.edu
JOHN H. HERRING, ASSOCIATE EDITOR / JHERRING@dos.state.ny.us

**JANUARY 2001**

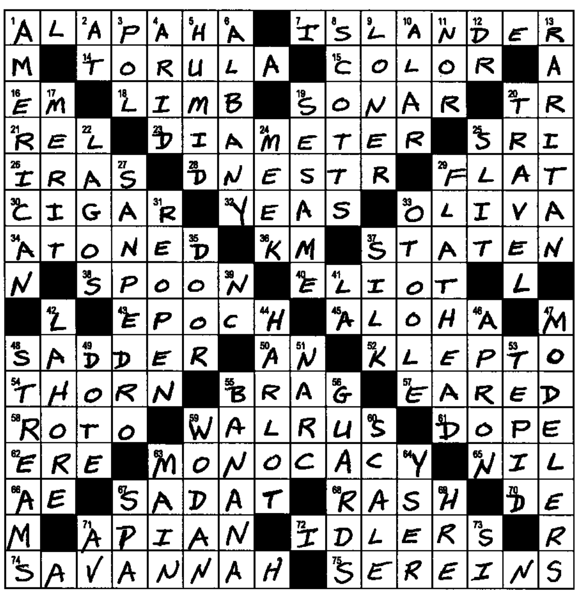
ERICH P. DITSCHMAN, ASSOCIATE EDITOR

**STORMWATER REGULATIONS & NONPOINT SOURCE POLICY – COMPLEMENTARY OR CONTRADICTORY?**

ERICH P. DITSCHMAN, ASSOCIATE EDITOR / E-MAIL: ditschman@mcnamee.com

**Submitting Articles for IMPACT** . . . Contact the Associate Editor who is working on an issue which addresses a topic about which you wish to write. Associate Editors, their e-mail addresses, and their topics are listed above. A less direct approach would be to contact the Editor-In-Chief Earl Spangenberg and let him know your interests and he can connect you with an appropriate Associate Editor. Our target market is the "water resources professional" – primarily water resources managers and such people as planning and management staffers in local, state, and federal government and those in private practice. We don't pay for articles or departments. Our only recompense is "the rewards of a job well done."

**Solution to Puzzle on pg. 44**



***Send us your feedback on this issue (comments on previous issues are also welcome) . . .*** *Water Resources IMPACT* has been in business for over a year. We've explored a lot of ideas. We hope we've raised some questions for you to contemplate. "Feedback" is your opportunity to reflect and respond. We want to give you an opportunity to let your colleagues know your opinions . . . we want to moderate a debate . . . we want to know how we're doing. Send your letters by land-mail or e-mail to Charles W. Slaughter (Associate Editor for this issue) or if you prefer, send your letters to Earl Spangenberg (Editor-in-Chief). Either way, please share your opinions and ideas. Please limit your comments to approximately 350 to 400 words. Your comments may be edited for length or space requirements.

**Go Ahead . . .**
**Push Our Buttons**

**Have Questions??**
**Contact AWRA HQ**

**By Phone / (540) 687-8390**

**By Fax / (540) 687-8395**

**By E-Mail / info@awra.org**

**Check Out Our Home Page At**
**www.awra.org**

**AWRA**
AMERICAN WATER RESOURCES ASSOCIATION
**4 West Federal St., P.O. Box 1626**
**Middleburg, VA 20118-1626 USA**
**Telephone: (540) 687-8390**

**ISSN 1522-3175**

WATER RESOURCES IMPACT

**DATED MATERIAL ENCLOSED**