THE CHANGING NATURE OF WATER MANAGEMENT AND ITS REFLECTION IN THE ACADEMIC LITERATURE

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The purposes of this paper are to (a) provide a perspective on the trends in and questions about water resources management as outlined by Robert Ward in the Forward to this edition of *Update* and similarly by other scholars (e.g. Rogers, 1993), and (b) to comment on how these trends and questions are being dealt with in the academic journal literature, particularly the *Journal of the American Water Resources Association* for which I currently serve as editor. My intent in juxtaposing these two issues is to make the case that Robert Ward's analysis is on the mark and that the community of water resources researchers has often been trailing the world of management rather than leading. Nevertheless, this is a problem that can be directly addressed as researchers continue their ongoing project of updating skills and knowledge and searching for the most relevant and useful topics for research.

Given the 2-5-year span of time it currently takes to go from conceptualization of research projects to finished research products that are put in use by the research and management community, we will have to wait until the next millenium to find out whether the projects the research community is now conceptualizing are consistent with these trends. My projection is that the research community is only partly on board due to (1) the large investments in intellectual capital that have been made in disciplinary training in the physical sciences and engineering as opposed to a broader, but not less rigorous, interdisciplinary education in the social and environmental sciences, and (2) the artificial divisions among disciplines that continues in the academic administrative and career reward systems. However, one of the clear trends Ward outlines is a change in the medium of research information exchange (from paper to electronic) which may accelerate the ideas-to-products cycle, while it simultaneously blurs the distinction between research (theoretical) and management (applied) information. Thus, sweeping technological changes may, for better or worse, help to prove me wrong, and so quickly that a reader might actually remember my erroneous projections and tell the world about it on the Web.

WHAT'S DRIVING TRENDS IN WATER RESOURCES MANAGEMENT?

The 20th Century was an era of national water resources infrastructure development, and therefore an era of big federal bureaucracies and big civil and environmental engineering projects. The 21st Century will be an era of local water resources management, and therefore an era when Americans of diverse interests and intellectual perspectives will, region-by-region, watershed-by-watershed, utility-by-utility, problem-by-problem, find a democratic way to define and implement "best" solutions to water resources conflicts on an ongoing basis. This transition from a single, national "iron triangle" to multiple, local pluralist polygons is both required by the logic of the issues to be faced, and well underway.

At century's end, Americans find themselves with a water resources development and pollution control infrastructure that is the most complex and most expensive in the world (Rogers, 1993). Despite specific shortcomings, the project of capturing water from the environment and delivering it at acceptable quality to where it is to be put to use have been successfully completed. Milwaukee's *cryptosporidium* outbreak notwithstanding, Americans have adequate and safe drinking water if compared to what is drunk elsewhere in the world or was drunk by Americans of past generations. The same can be said of the water supplies for irrigators and industries. Navigation, hydroelectric power, and flood control works are developed to close to their economic potential. But resolving these large and critical social tasks (tasks which remain unresolved in most of the developing world) has left Americans with a new set of complex social and ecological issues. Once prodigious migrations of anadromous fish are pressed to extinction by overfishing, dams, and siltation from forestry activities. The Great Lakes have lost nearly all their native fish populations, and the exotic species that have replaced them are often either contaminated with traces of toxic industrial chemicals or proliferating uncontrollably in the absense of natural predators (e.g. the zebra mussel). Indian lands and terrestrial ecosystems are submerged beneath reservoirs (Reisner, 1993). Stream after stream in urbanized and intensively agricultural areas carry few of the ecological or aesthetic values they once did (Dopplet etal., 1993). Whole regions of wetlands have been drained (Dahl and Johnson, 1991). Aquifers are contaminated by pesticides, petroleum, or other pollutants and cleanup efforts have met with only limited success (Hallberg, 1989). Floodplains, seemingly protected by levees or dams, have filled with buildings that are now increasingly vulnerable to flooding, which in turn may intensify due to climatic change (Myers and White, 1993). More subtlely, but no less importantly, the distribution of population in the country increasingly misfits the distribution of available, renewable water resources due to the "Sunbelt migration." A number of examples from the Southwest or Florida readily come to mind where regional changes in economic activities and human settlement have generated water resource problems. Socio-economic forces that drive the changing location of industry, agriculture, and people's homes, also, therefore, drive water resources problems. Yet, water resources are often peripheral to the decision making arena in which ongoing changes in economic geography are determined (Waterstone, 1992). Particularly east of the Rocky Mountains where most land is held in private hands, this means that many of the critical variables that determine water supply, water demand, and the condition of watersheds are not controlled by water resources planners, yet the impact of these variables on water resources must be managed. American society is just now beginning to build the countervailing local institutions that have the authority and capacity to influence, if not control, social forces that affect land and water resources in the interests of watershed management.

Twenty-first Century resource management issues thus differ from resource development issues of the Twentieth. They include implementing water conservation, reuse, and reallocation; determining the extent to which Indians will be the water brokers of the future; management of ground water quantity and quality; wetland protection and restoration; control of contaminants and sediment derived from agricultural and urban run-off; adapting the built environment of floodplains and coastal zones to increasing risk of flooding due to climatic change; restoring streams and aquatic ecosystems; managing increasing recreational use of lakes and streams. These 21st Century issues are very site-specific and oriented around the interaction between land and water, between people and water, and even between people and land, interactions that change with changing physical and human geography.

The water frontier has closed. In the southwest and some areas elsewhere, this means that there is no fresh water left to develop; rivers run dry and water tables are falling. New water resources must be drawn from existing developed uses. Elsewhere, it means that development of additional water meets stiff resistance from direct and indirect users of the water in its "undeveloped" state, or from those who convincingly point out that it is more economically and environmentally sound to use more efficiently water that has already been developed. In this sense, the veto by the U.S. EPA of an Army Corps of Engineers permit to build Two Forks dam on the South Platte River near Denver, CO on the grounds that the reservoir would flood a valuable trout fishery and scenic canyon, rather than because it would remove water from the overallocated Colorado Basin (Zhai, 1994), is symptomatic of the social forces closing the water frontier.

Socially, economically, and environmentally responsible (i.e. "sustainable") water resources management has thus become very difficult to achieve and a goal that does not yield to simplified, one-size-fits-all solutions such as building dams and levees or organizing markets that allocate water like gasoline. This is particularly true of the aquatic and wetland ecosystems of the U.S., the state of which varies tremendously, and is often poor (Doppelt, et al. 1993). As public resources, they suffer directly from the tragedy of the commons; that is, aquatic and wetland ecosystems struggle to thrive largely as an afterthought of land and water use decisions made for other economic, social and political purposes. That is also why non-point or diffuse pollution problems are so widespread and so central to the challenges facing water resources management. Costanza et al. (1997) have estimated the value of the Earth's ecosystem services as equal to or greater than gross global product, thus identifying a second economy of ecosystem services. This raises the stakes for aquatic and wetland ecosystems since, along with ocean shore ecosystems (estuaries, seagrass, algae beds, coral reefs), these are by far the highest value per hectare ecosystems on the planet. Thus for both ecological reasons (their high production of ecosystem services) and social reasons (their shared nature and consequent vulnerability to behavior based on narrow goals), management of watery ecosystems presents both a great challenge and an indicator of our progress in managing the planet.

For all of these reasons, water resources management is beginning to move out of the river channels and sewage treatment plants and into the watershed; to step away from the dam sites and into the factories, farms, and homes where water is used; to reach out from offices in Washington and into local schools, civic centers, and tribal councils; to expand from a narrow technical curriculum to embrace a multi-disciplinary and more people-oriented approach. Civil engineers employed by the Army Corps of Engineers, the Bureau of Reclamation, the Tennessee Valley Authority, and so on, are being replaced by economists, ecologists, regulators, lawyers, local citizen's groups, tribal councils, and traders in markets as the next generation of water resources managers. What these placed-based institutions will be managing is not just water, but watersheds, and the often sophisticated people and often degraded ecosystems they contain. They will be "adaptively managing" (as opposed to "planning") them in a political environment well-described as "organized anarchy" or as a "complex adaptive system," guided in their decisions by "civic science" (Lee, 1993), where each policy adopted is viewed as an experiment that advances social learning.

REFLECTION OF THESE TRENDS IN THE ACADEMIC LITERATURE

As the editor of the *Journal of the Water Resources Association* since 1994 (until 1997, the *Water Resources Bulletin*), I am in a position to gage the flow of academic work on water resources. Since *JAWRA*, reflecting the mission of AWRA, is an explicitly inter-disciplinary journal, and as "inter-disciplinary" and "applied" necessarily co-vary, if the trends discussed above were to be reflected in the academic literature on water resources, they would be evident in *JAWRA*. Fortunately, I have available for comparison the results of a recent survey of the AWRA membership (Table 1) and a breakdown of paper submissions to *WRB/JAWRA* categorized by disciplinary and topical focus (Table 2).

A comparison of Tables 1 and 2, together with inspection of open-ended comments given in response to the AWRA questionnaire, indicate that managers need more information in two broad areas that are being insufficiently supported by research. First is applied problem solving, particularly in the form of comparative case studies where successful and unsuccessful experiences in addressing the complex, integrative 21st Century management issues can be documented and made applicable to practicioners elsewhere. Managers are looking for case studies so that they can learn in an inductive manner about how others are dealing with the issues they face in their professional arenas. A critical factor in determining the usefulness of case studies is external validity, or defining the domain of applicability for lessons learned, successes and failures achieved, in one particular context. A good example here is the recent success achieved in the New York City watershed, where the NYC water department successfully negotiated with Catskill farmers to reduce non-point source pollution, thus allowing the city to avoid several billion dollars of investment in water filtering. There are some very good lessons to be learned here about replacing expensive technological investments with innovative ways of designing win-win solutions among stakeholders, implemented as BMPs for watershed management. However, the NYC watershed (or, more accurately, "region of water capture") has several thousand water customers per farm. How applicable are these lessons to the many rural watersheds suffering from non-point pollution of water supplies where there are only several water users per farm? How far can the theme of "water utility supported watershed management for improvement of drinking water quality" be pushed in geographic contexts differing from the one in which these innovations were originally made? Are there additional deals waiting to be made on the model of MWD's (Met) deal to fund water conservation in the Imperial Irrigation District in exchange for some of the water so conserved? What are the constraints and possibilities? Later this year, *JAWRA* will feature a special issue on "Human Dimensions of Watershed Management" that will focus on this type of comparative, people-oriented, problem-solving.

Table 1. Areas of Interest for Future Articles and Information for Members of AWRA

Rank	Topic	Percent Including Among Top Five Topics
1	Surface water hydrology	46.7
2	Watershed planning	45.1
3	Water quality	43.4
4	Water policy, management, and law	42.3
5	Coordinated resource management	30.5
6	Ground water	28.9
7	Modelling and statistics	26.3
8	Water use	23.8
9	Watershed management	23.3
10	Urban hydrology	22.2

Table 2. Topical focus of 341 Submissions to *Water Resources Bulletin/JAWRA*, 1995-April, 1997

Topical Focus	Number of Papers (%)	
Primarily Physical Sciences		265 (*78*)
Water Quality	76 (*22*)	
Surface Water Hydrology	42 (*12*)	
Watershed Management	36 (*11*)	
Ground Water Hydrology	34 (*10*)	
Civil & Env. Engineering	33 (*10*)	
Hydrometeorology	30 (*9*)	
Geographic Info. Systems	14 (*4*)	
Primarily Social Sciences		59 (*17*)
Dialogue on Water Issues	22 (*6*)	
Social & Political Science	19 (*6*)	
Water Economics	18 (*5*)	
Primarily Biological Sciences		17 (*5*)
Aquatic Biology & Limnology	17 (*5*)	

The second knowledge niche managers are looking for researchers to fill is policy discussions that analyze the impact of social, political, economic, and technological trends on water resources and that integrate science, policy, and management. It is unfortunate that science and decision-making have developed as almost separate cultures in the U.S., for clearly there is a demand for policy analysis that is scientifically informed and science that is policy-relevant. Commiting the scientific community and educational institutions to achieve these has been termed "A New Social Contract for Science" by the President of the American Association for the Advancement of Science (Lubchenco, 1998). Publication outlets for such information have grown rapidly of late with the introduction of the "Dialogue on Water Issues" in *JAWRA* in 1994, the introduction of *Water Policy* by the World Water Council last year, and the progress that has been made here in *Update*.

While surface water processes and water quality are scentific topics with enduring interest, highly technical analyses and modeling exercises were identified as overabundant by AWRA members and therefore not in high demand (Table 1). Nevertheless, Table 2 shows that 78% of the submissions of papers to *JAWRA* are oriented toward the physical sciences of surface and ground water hydrology, water quality chemistry, engineering and hydrometeorology. Given the particular inter-disciplinary niche in knowledge space that *JAWRA* holds, as compared to *Water Resources Research*, and the ASCE *Journal of Water Resources Planning and Management* for example, these trends are likely much more skewed in the water resources literature as a whole, with a critical shortage of information on applied case studies, integrative work, and social scientific topics generally.

CONCLUSION

The analysis provided suggests that academic research is not keeping up with the shift in management needs from physical science and engineering to social science and systems approaches that integrate across the physical, social, and ecological sciences in an applied context. Though underfunded, the joint NSF/EPA (and this year USDA) program in *Water and Watersheds* initiated in 1995, with its inter-disciplinary approach, reflects well the research needs of the new water management arena and goes far to redefine the research agenda in a way that promises to yield the kind of scientific results that can guide 21st Century water management. An accompanying program in *Decision-Making and Valuation for Environmental Policy* also focuses on the kind of issues discussed above. To the extent that academic researchers join with their colleagues from other disciplines and use these funding programs to guide their choices of research topics to explore, the research community will be providing the management community the knowledge it needs to meet its new list of 21st Century challenges.

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Christopher Lant received his Ph.D. in Geography from the University of Iowa in 1988. He currently serves as editor of the *Journal of the American Water Resources Association* and as Chair of the Geography Department at Southern Illinois University-Carbondale. His research interests are in U.S. environmental policy as applied to wetlands, soil and water conservation, and non-point source pollution.