Minnesota Water 1990

Facing the Environmental Challenges of the 1990s

Collection of Conference Abstracts

Minnesota Environmental Quality Board
Water Resources Research Center
April 1990

Celebrate
MINNESOTA WATER
1990

MONDAY AFTERNOON CONCURRENT SESSIONS

SECTION 1: **Local Water Planning and the State Water Plan**: Minnesota East Ballroom; Organizers: J. Wells, EQB, Water Resources Committee, and L. Yohe, The International Coalition

1:20 Opening remarks: J. Wells and L. Yohe

1:30 J.C. Ditmore and M.D. Lundberg, Environmental Quality Board, St. Paul. *State water planning barriers and opportunities.*

1:55 D.C. Blinks, Olmsted County Water Policy Advisory Committee, Rochester. *Challenges to overcoming barriers to holistic water management at the county level.*

2:20 D.H. Ogaard, MN Bd. of Water and Soil Resources, St. Paul. *Recommendations of the 1989 Metropolitan local water management task force.*

2:45 L. Yohe, International Coalition for Land and Water Stewardship in the Red River Basin, Moorhead. *Red River Valley surface water management: a holistic approach to rivers and lakes.*

3:10 Refreshment Break

3:30 P.K.B. Hunt, Zumbro/Root River Joint Powers Board, Winona State Univ., Rochester Center, Rochester. *Regional groundwater implementations via local comprehensive water management plans in southeast Minnesota.*

3:55 Panel: *Barriers and opportunities to holistic management of water.* Members: M. McGregor, Mississippi Headwaters Board, H. Quade, Mankato State Univ., R. Nargang, MN DNR, G. Hollenstein, Izaak Walton League.

STATE WATER PLANNING BARRIERS AND OPPORTUNITIES. John C.Ditmore, and Marilyn D. Lundberg, Environmental Quality Board, 300 Centennial Office Building, 658 Cedar Street, St. Paul, Minnesota 55155

Background. The importance of water and questions about how to manage it are reoccurring themes throughout Minnesota's history. The drought in the mid-1970s prompted the creation of the Water Planning Board to develop the Minnesota Framework Water Plan (1979).

Passage of the Metro Water Management Act in 1982 and the Comprehensive Local Water Management Act in 1985 focused the role of local government and provided the basis for a local-state partnership in water management. In 1987, the LCMR provided grants administered by EQB to 52 counties formed into six groups to develop comprehensive water plans. The plans are now nearly completed.

The 1983 merger of the functions of the Water Planning Board into the EQB, and the 1987 creation of the Board of Water and Soil Resources (BWSR) combining the functions of the Soil and Water Conservation Board, the Water Resources Board, and the Southern Minnesota Rivers Basin Council unified state and state-local activities.

Present Conditions. The present system of water management in Minnesota provides numerous barriers to holistic management of water. At each level there are numerous agencies, departments, interest groups, rules, and programs that tend to direct attention to specific issues or problems.

Federal programs and policies also are fragmented and put pressure on Minnesota to separate programs and issues. Pressure to act may result in the imposition of solutions being imposed before alternatives are fully considered.

Population pressures stress sensitive areas and local units of government often have not exerted the kind of controls needed to manage growth. Management schemes that adequately address both quality and quantity for surface and ground water, as well as related land use and air toxic issues require a level of intergovernmental coordination and planning that has not yet been achieved.

To address state fragmentation, the EQB formed the Water Resources Committee (WRC) in 1985 to coordinate interagency efforts and to guide plans and strategies. The WRC is composed of agency, university, and citizen representatives.

At the local level the state is looking to comprehensive local water plans to furnish direction and to sort out the responsibilities of the numerous local interests. Local water planning provided a good opportunity to bring together local and state efforts to address water issues holistically. While this process has had its share of problems, it provided an impressive first step at putting together the local-state partnership.

The Ground Water Protection Act of 1989 requires the EQB to carry out a number of new water assignments. These include: 1) updating the Minnesota Water Plan; 2) developing a water monitoring plan; 3) developing an information and education plan; 4) evaluating water research needs and priorities; and 5) compiling water resources trends.

The Act builds upon the comprehensive water planning efforts across the state by providing plan implementation grants through BWSR. This continues the local-state partnership for water management. The state looks to local government to demonstrate leadership to protect and manage water resources.

The WRC is leading the state water planning effort. This process offers a unique opportunity to use the information developed in comprehensive local water plans and information gathered by the state to shape our future.

Future Possibilities. The Minnesota Water Plan provides an immediate opportunity to recommend measures to bring us closer to holistic management. The plan will contain a Ten-Year Agenda that will provide a long-range guide to Minnesota's water needs. It will also contain priorities for the 1991-1993 biennium. The plan is intended to shape future policies and programs.

Recommendations are needed on how the state can work better with local governments to ensure water resources are protected. Is the state response sufficiently unified, or can ways be suggested to improve its actions and programs? Should the state have regional centers to better deliver technical assistance? Should more effort be made to tie together permits dealing with air, land, and water? Should quality and quantity issues be linked through integrated state project aid?

Is the existing structure adequate to protect and manage our rivers and ground water systems? Is a special structure needed to focus comprehensive local water plans around river basins or ground water systems? What should be the characteristics of such a structure?

How much holistic management is desirable? The present system has a number of checks and balances. Would more integration cause the loss of valuable components? Is enough known to manage the entire system?

The Minnesota Water Plan can be used to unify efforts and to clarify individual roles. Water priorities, water monitoring needs, water information systems, and information and education needs will be examined in the context of tying various governmental levels and activities together. This requires working toward a local-state partnership that will provide the best protection for water.

A course of action must be set that builds on the public concern for environmental protection; informs people about actions needed to safeguard our resources; and involves citizen, local governments, and the state in taking actions to protect our resources.

CHALLENGES TO OVERCOMING BARRIERS TO HOLISTIC WATER MANAGEMENT AT THE COUNTY LEVEL. Doris C. Blinks, Olmsted County Water Policy Advisory Committee, 2715 Salem Road SW, Rochester, Minnesota 55902

Barriers to holistic water management experienced by Olmsted County can be categorized as institutional, informational, financial and political.

Institutional Barriers. Compartmentalization of responsibility for water among multiple state agencies result in single-issue water programs which do not address the needs of a water unit as a whole; turf and budget protection and competition; lack of accountability; and avoidance of tougher or less popular needs. In this process, county designated priorities are ignored in order to participate in state programs. While there are fewer water responsible agencies in Olmsted County, the traditional bureaucratic structure causes failures of communication and coordination, as well as buck-passing, turf protection, and resistance to change.

Institutional Challenges. A stronger centralized state authority, with enough clout and accountability for results, could guide more effective use of state funds and staff toward long-range and integrated management within individual water units. It could also improve the currently irregular communication among levels of government. New administrative procedures that overcome the traditional departmental segmentation of water responsibilities are currently being reviewed by Olmsted County.

Informational Barriers. The greatest barrier to holistic water management lies in each individual's attitude toward acknowledging and accepting responsibility for water problems and change. Lack of information about certain water problems, such as lawn chemicals and urban runoff, hinder a well balanced urban/rural approach to water management.

Informational Challenges. The greatest challenge is to develop educational and information-transfer programs that are really effective in reaching into the minds of all of us--not just decision-makers, legislative leaders, and technical staffs, but most of all, the individual citizen, rural, suburban, or urban.

Financial Barriers. Biennial funding restricts the long-range view which is necessary to really do the job of managing water effectively. Allocated money is used up by state agencies before it reaches the local level and actual active implementation. State and federal program responsibilities are being passed down to counties without accompanying funding. Counties have already tightened up their budgets under the levy limit to the point that it is impossible to add a major new program.

Financial Opportunities. Increased public awareness that environmental programs need stable and long-term commitment is indicated by the public response to the Environmental Trust Fund. Translating that awareness into action will permit the kind of programs necessary to achieve the nondegradation goal for Minnesota waters. New sources of funding must be found; possibilities exist such as water consumer fees, storm water utilities, or fees for the use of water as a waste management receiver.

Political Barriers. Rural mistrust of government and resistance to regulation and change. Short-term interests have the political clout to derail pro-active programs. Water systems are regional and don't correlate with political boundaries. Bureaucracies bend programs toward the currently politically "in" issues and avoid unpopular stands in order to protect their turf.

Political Opportunities. Strong and far-sighted leadership by the Legislative Water Commission; a 10-year state water plan which develops realistic, achievable goals and focuses on the most necessary problems taking into consideration regional differences and local priorities; continuation of the regional cooperation which has been developed in the Chapter 110B water planning process. The challenge is to succeed.

RECOMMENDATIONS OF THE 1989 METROPOLITAN LOCAL WATER MANAGEMENT TASK FORCE. Donald H. Ogaard, Minnesota Board of Water and Soil Resources

A special task force established by the legislature completed its job on December 15, 1989 by adopting a report entitled "Report of the Metropolitan Local Water Management TAsk Force to the Governor and Legislature of the State of Minnesota." The task force was named the Metropolitan Local Water Management Task Force (MLWMTF) and was established by Article 9 of the 1989 Groundwater Protection Act. Senator Dahl, a member of the MLWMTF, was the author of the legislation which established the Task Force. Donald Ogaard, Chairman of the Board of Water and Soil Resources, was elected as its chairman.

The mission of the Task Force was to investigate the overall effectiveness of local water management activities in the seven-county metropolitan area. The original legislation provided for the review of eight issue areas. Due to the inter-relationships of these issues, the task force deliberations essentially consolidated them into five (5) general issue areas: 1)"509" Plan content and implementation, 2) oversight over plan implementation, 3) ditch management and financing in the metro area, 4) structure of metropolitan Water Management Organizations (WMOs), and 5) financing of metro water management organizations.

Emphasis was placed on the assessment of the "509" water planning act (Minnesota Statutes Sections 473.875 to 473.883) since this is the vehicle which is supposed to drive local water management in the seven-county metro area.

The law provided for the appointment of 22 Task Force members. The membership included representation from the following agencies, groups, or people: three (3) members of the Senate, three (3) members of the House of Representatives, three (3) members of the Board of Water and Soil Resources, one (1) citizen at large, the Association of Metropolitan Municipalities, the Minnesota Association of Watershed Districts, the Association of Soil and Water Conservation Districts, a Watershed Management Organization, the Association of Minnesota Counties, the Metro Inter-County Association, the Consulting Engineers Council, the Reinvest in Minnesota Coalition, the State Planning Agency, the Department of Natural Resources, the Pollution Control Agency, and the Metropolitan Council.

The Task Force came up with a total of 31 specific recommendations. Among the more significant recommendations was to require the BWSR to promulgate rules for the content of "509" plans, the structure of joint powers agreements, content of annual reports to the BWSR, content of local water plans, and the content of an assessment of the condition of public ditch systems in the metro area. Among their other recommendations were: a clarification of the authority and procedure for managing public ditches under "509" authority, requiring the BWSR to develop a model Environmental Management

Ordinance for use by local governments in implementing local water plans, and a recommendation to make local ad valorem levies for water planning and plan implementation exempt from any overall levy limitations.

The MLWMTF met a total of 10 times from July 20 to December 15, 1989. The meetings took the most part of a day and some ran beyond. Testimony was heard from the State Planning Agency, the Department of Natural Resources, the Pollution Control Agency, the Association of Metropolitan Municipalities, the Metropolitan Council, two joint powers watershed management organizations, two metro watershed districts, and the Association of Soil and Water Conservation Districts.

Other input was received via two surveys conducted to gather data from local governments. One was a written survey conducted by the Association of Metro Municipalities of their 67 members. The second was a phone survey of the 46 metropolitan watershed management organizations (WMOs) conducted by BWSR staff.

An important recommendation of the Task Force was that Water Management Organizations should all be an on-going water management entity. This was early on in the process and helped to focus on revisions to the current law to ensure that the "509" program evolve from a planning function to an implementation function.

In arriving at its final recommendations, the Task Force considered the oral testimony, the results of the two surveys, and written input from the League of Women Voters and the Minnesota Association of Watershed Districts.

RED RIVER VALLEY SURFACE WATER MANAGEMENT, A HOLISTIC APPROACH TO RIVERS AND LAKES. Lance Yohe, The International Coalition for Land and Water Stewardship in the Red River Basin, Moorhead, MN 56561.

The Red River of the North is near the geographic center of North America. It drains parts of North Dakota and Minnesota in the United States and parts of Manitoba and Saskatchewan in Canada. The total area in the United States watershed is 39,200 square miles, of which 17,806 square miles is in Minnesota. In Canada the watershed is 69,238 square miles.

In Minnesota part of the Red River basin includes 15 counties that formed the Northwest Minnesota Joint Powers Board to do Comprehensive Local Water Plans. These counties are Traverse, Stevens, Grant, Wilkin, Clay, Otter Tail, Becker, Polk, Norman, Mahnomen, Red Lake, Pennington, Marshall, Kittson, and Roseau. Four other counties are also partially in the Red River basin; Beltrami, Lake of the Woods, Clearwater, and Koochiching.

The Red River basin was formed 10,000 years ago by a glacier. The resulting topography is a large area that is almost flat in the center. This area is covered with rich top soil over heavy clay. The edges of the basin are steeper ridges of sand and gravel.

The Red River basin has a number of well defined river tributary systems that all drain into the Red River and flow north into Canada. Tributaries of the Red meander through a chain of lakes in Minnesota in the eastern edge of the Red River basin. This is one reason to look at the system as a unit, since the lake and river systems are so intertwined.

Problems arise in the basin since most of the population, particularly urban, depend on surface water supplies for drinking water. This makes holistic management of the water supplies, especially during periods of drought, essential. In the Red River basin management of water for low flow periods is difficult because the area is prone to severe flooding at various times during the year. Finding a balance that deals with water supply questions is the second reason why a holistic approach is needed.

A third reason for a holistic approach is water quality. The groundwater resource is used, but not well managed. In some areas of the basin this resource is unusable. Finding a balance between groundwater and surface water, (which is largely affected by nonpoint source pollution) is crucial to the area.

A final reason for a holistic approach is related to the intense agricultural use of the land resource in the area. Land use practices, like drainage, that impact water supplies and erosion that impact water quality, illustrate the need for a holistic approach.

In this part of Minnesota, the Red River basin counties participating in the Northwest Minnesota Comprehensive Local Water Planning project have recognized the need for a holistic, balanced approach to managing their surface water resources. They have planned together. They are now beginning to work to implement solutions together. They are taking a holistic approach which recognizes how surface water, river and lake systems, relate and how land impacts water.

REGIONAL GROUNDWATER IMPLEMENTATIONS VIA LOCAL COMPREHENSIVE WATER MANAGEMENT PLANS IN SOUTHEAST MINNESOTA. Pamela K.B. Hunt, Zumbro/Root River Joint Powers Board, Winona State University-Rochester Center, Rochester, MN 55904

Nine counties in Southeast Minnesota have developed Local Comprehensive Water Management Plans. Dodge, Fillmore, Goodhue, Houston, Mower, Olmsted, Rice, Wabasha and Winona Counties have proposed numerous implementations to protect and manage their water resources. The emerging priorities and issues are focused on groundwater quality. The issue of hydrogeologic susceptibility is an issue for the counties due to our karst geology in Southeast Minnesota. Progressive implementations proposed in the plans is to develop "water management areas".

The initial step for assessing water management areas is developing hydrogeologic databases. The action includes compiling, mapping and automating county hydrogeologic data including topography, soil characteristics and depth, bedrock geology, data points (well logs, bedrock outcrops, surface water data points), floodplain, shoreland, surficial geology, lakes, streams, drainage ditches, wetlands, springs, sinkholes, ground and surface water quality data, primary recharge areas for municipal wells and land use.

Secondly, criteria will be developed using the hydrogeologic maps and socio-economic information to delineate water resource management areas that require additional controls on activities that are a potential source of pollution. Water management areas may include primary recharge areas for municipal wells, hydrogeological sensitive areas, floodplains, and shorelands. Identify land use activities that represent potential sources of pollution and develop appropriate programs that administer land use activities within the water management areas. Amend land use plan to address the water management areas where additional controls on land use activities are necessary to protect water resources.

The time frame for these actions begins in 1990 and continues through 1995. Staff and funds from county departments and state agencies are required to accomplish these implementations. These actions as well as others are dependent on continuing the state-local partnership that the region has experienced during the planning process.

The regional office also acknowledges the efforts of Dr. Nancy Jannik, Winona State University and Georgianna Meyer, Minnesota Pollution Control Agency for their input on the development of these implementations.

SECTION 2. Agricultural Management Practices to Minimize Surface and Groundwater Contamination: Minnesota West Ballroom; Organizers: J. Anderson, Center for Agricultural Impacts on Water Quality, Univ. of MN, and J. Birkholz, MN Board of Water and Soil Resources

1:20 Opening remarks: J. Anderson and J. Birkholz

1:30 G.W. Randall, Southern Experiment Station and Center for Agricultural Impacts on Water Quality, Univ. of MN, Waseca. *Nitrogen management to prevent groundwater contamination.*

1:55 R.L. Becker, Department of Agronomy and Plant Genetics, Univ. of MN, St. Paul. *Pest management strategies to minimize surface and groundwater contamination.*

2:20 K. Crookston, Dept. of Agronomy and Plant Genetics, Univ. of MN, St. Paul. *Sustainable agriculture research efforts and projects.*

2:45 J. Anderson, Dept. of Soil Science, Univ. of MN, St. Paul. *MES water quality priorities and efforts.*

3:10 Refreshment Break

3:30 J.C. Brach, U.S. Dept. of Agriculture, Soil Conserv. Serv., St. Paul. *Agriculture and water quality: best management practices for Minnesota.*

3:55 D.D. Breitbach, U.S. Dept. of Agriculture, Soil Conserv. Serv., St. Paul. *Soil Conservation Service pest and nutrient management standards and specifications.*

4:20 S. Strand, Attorney General's Office, St. Paul. *Agriculture and water quality: liability issues.*

4:45 Discussion and questions

NITROGEN MANAGEMENT TO PREVENT GROUNDWATER CONTAMINATION. Gyles W. Randall, So. Expt. Stn. and Center for Agricultural Impacts on Water Quality, Univ. of Minnesota, Waseca, MN 56093

Current agricultural production systems are being linked closely to the occurrence of nitrates (NO_3) in the groundwater. Sources of nitrogen (N) that contribute to NO_3 in agriculture include fertilizers, manure, legume crops that fix atmospheric N, and soil organic matter. Farmers must have a clear understanding and knowledge of the impact of the latter two as they consider management of fertilizers and manure to optimize profitability and minimize groundwater contamination.

Studies have been conducted throughout Minnesota over the last 10 to 15 years to evaluate sources of N, rates, times, and methods of N application, and the effect of previous crop and tillage on N utilization by the crop and NO_3 loss to the environment. Experiments conducted on the poorly drained soils showed that previous crop, rate of fertilizer N, and time of N application affected the amount of NO_3 lost through tile discharge. Increasing the rate of application to continuous corn from 120 to 180 lb N/A resulted in a substantial increase in NO_3 losses. Fall application of 120 lb N/A showed equal losses to spring application of 180 lb/A. Nitrate losses under continuous soybeans without any fertilizer N were similar to continuous corn with 180 lb N/A applied in the spring. Tillage system (moldboard plow vs. no tillage) has not affected NO_3 losses from these soils, but average yields have been 8% lower with no tillage.

Recent experiments on the silt loam soil in the Karst area of southeastern Minnesota dramatically show the importance of N rate (fertilizer as well as manure) and previous crop. Rates of N application, regardless of whether the source is fertilizer or manure, that are above the plants' requirements quickly lead to elevated levels of NO_3 below the root zone. These effects are exacerbated when proper credits from previous alfalfa crops or manure applications are ignored. Significant amounts of NO_3 can mineralize from these systems and if not accounted for can contribute to NO_3 in the groundwater. Results over the last three years indicate no advantage for split and sidedress applications of fertilizer N over a preplant application of anhydrous ammonia. Yields and NO_3 movement through the profile have been similar for both the chisel plow and no tillage systems. Nitrate N concentrations in the soil water below the root zone (5') were extremely low (1 mg/L) when no N was added to continuous corn, but when profitability to the N fertilizer was optimized at about $180/A, NO_3-N concentrations averaged about 15 mg/L. Realistic manure applications increased NO_3-N concentrations at this depth to 79 mg/L.

Coarse-textured, irrigated soils of central Minnesota have also received much research attention. Due to rapid percolation rates, N and water management are critical on these soils. Split applications of N during the growing season, nitrification inhibitors, proper application rates, realistic yield goals, and precise water management all can lead to improvement of N utilization by the crop while minimizing NO_3 losses to the groundwater.

Awareness and educational programs will need to be offered continually to growers, dealers, consultants, etc. to facilitate and stimulate improvement in N management that will result in reduced NO_3 losses to groundwater.

PEST MANAGEMENT STRATEGIES TO MINIMIZE SURFACE AND GROUNDWATER CONTAMINATION. **Roger L. Becker. Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, MN. 55108.**

The Problem. The potential for ground and surface water pollution with pesticides is a growing concern in Minnesota. Good land stewardship dictates that pesticide characteristics must be assessed for their ground or surface water pollution potential. No longer can pesticides be chosen only for the most effective and economical pest control. Growing public concern and increasing frequency of detections of minute levels of pesticides in groundwater will result in regulatory action, and difficult, expensive problems to remediate if corrective measures are not taken.

Particularly sensitive areas are the karst topography in southeast Minnesota and permeable sands with shallow water tables found in central Minnesota and along glacial outwash areas. Atrazine is the most commonly detected herbicide in Minnesota well monitoring studies, accounting for over 90% of well samples with positive detections for pesticides. Sinkholes and shallow soil over porous, fractured limestone bedrock pose a real problem for managing certain pesticides such as atrazine in the karst area. The same situation also exits where permeable sands over shallow water tables occur. Alternatives to atrazine use in these areas may have to be used to reduce pollution potential. Much of the pesticide contamination of Minnesota ground water aquifers could be eliminated through this practice alone. Also, other pesticides have groundwater advisory statements on their labels. These compounds should be used in sensitive areas only after assessing site specific pollution potential.

Pesticide levels being detected in groundwater are generally less than one part per billion (ppb) and are typically below current health risks limits considered safe for drinking water. These levels often represent less than 1/1000th of the amount applied to field sites alluding to the difficulty in managing pesticide pollution. Point source concerns are often suspect if levels over a few ppb are detected.

The Solution. Point source problems are those directly attributable to a confined area, event, or site such as a mixing or manufacturing sites. Point source contamination may be responsible for a large portion of pesticide detections in wells in some areas of the state. They are relatively easy to correct. Point source problems can be reduced by the following:

- Mix chemicals in the field away from wells and water sources. Use a "water only" nurse tank.
- If chemicals must be mixed at the well site, use hoses to maintain at least a 150 ft. buffer from the well to the spray tank.
- Keep filling hoses out of the spray tank, use check valves, and do not leave tanks unattended while filling to avoid backsiphoning or overflow.
- Never dump rinsate or concentrated product in a localized area. Dispose of rinsate by applying to a labeled crop site.
- Triple rinse pesticide containers before disposal or return.
- Properly construct, grout, and case new well construction. Properly cap and seal abandoned wells.

Nonpoint source pollution occurs over a broad, generally ill-defined area and the direct cause of contamination may not be readily apparent. Leaching from general field applications within labeled guidelines would be an example of nonpoint source pollution. This problem is more difficult to correct or even identify. Steps to reduce nonpoint pollution from pesticides would be to:

- Leave buffer strips around sinkholes, streams, and bodies of water.
- Band apply herbicides as opposed to broadcast applications to reduce the overall pesticide load on the environment.
- Use pesticides with high unit activity, short persistence, strong soil adsorption,

and low water solubility.
- Properly calibrate sprayer equipment to avoid over application.
- Use practices such as crop rotation and scouting, and for weed control, use rotary hoeing, cultivation and cover crops in addition to, or in lieu of herbicides.
- Apply pesticides only when necessary.
- To reduce surface water pollution, use good soil conservation practices to reduce soil sediment and water runoff from fields.

To select pesticides with properties to reduce ground and surface water concerns, the University of Minnesota Extension Service (MES) and the Minnesota Soil Conservation Service (SCS) have teamed up to provide reference materials to assess the potential of pesticides to cause leaching or surface runoff concerns. A publication titled **Pesticides: Surface Runoff, Leaching, and Exposure Concerns** (AG-BU 3911) available from the University of Minnesota, provides information on 1) Physical properties of commonly used pesticides which influence movement off-site through leaching or surface run-off, 2) Comparison of possible toxicological risks of these pesticides, and 3) Restricted use pesticides and reason for Environmental Protection Agency designation.

This information on pesticide properties can be used to make relative comparisons of the potential of a pesticide to cause water pollution. Key properties included are:

Soil Adsorption (K_{oc}): K_{oc} is a measure of soil adsorption, the tendency of pesticides to be attached to soil particle surfaces. Higher values indicate a pesticide that is very strongly attached to soil and is less likely to move unless soil erosion occurs.

Water Solubility: Solubility of a pesticide will affect how easily it washes off crop residue and leaches through soil.

Persistence (Half-life): Half-life is the time required for pesticides in soil to degrade to one-half of their previous concentration. In general, the longer the half-life, the greater the potential for pesticide movement before degrading.

The EPA has developed "Red Flags", or alerts to identify pesticides with possible leaching problems. "Red Flag" values for pesticide properties discussed above are:

Water Solubility	:	**Greater than 30 ppm**
Soil K_{oc}	:	**Less than 300-500**
Soil Half-Life	:	**Greater than 21 days**

If an individual pesticide property meets these criteria, a "Red Flag" goes up. However, it is not individual properties, but rather their **interaction** that determines the behavior of a pesticide in the environment. For example, Treflan^R, a herbicide with persistence similar to atrazine (60 day half-life) would be expected to leach based on this property alone. However, Treflan^R is so insoluble in water (0.3 ppm) and so tightly held to soil (7000 K_{oc}) that it will not leach, despite its relatively long persistence. Thus, Treflan^R has a "small" potential to leach. Atrazine has solubility and adsorption values that are not extreme enough to compensate for it's persistence and has a "large" potential to leach.

Soils, like pesticides, also differ in their leaching and surface runoff ratings. Ratings for pesticide leaching and runoff based on soil properties can be found in the **Soil Ratings for Determining Water Pollution Risks for Pesticides**, available at county SCS or Extension offices. The SCS has developed a Pesticide Leaching Matrix and Surface Runoff Matrix which combine soil and pesticide ratings. By using the matrix, it is possible to determine how the leaching or surface runoff properties of a soil may influence pesticide movement. This information can help pesticide users minimize surface and groundwater contamination through wise pesticide selection. Remember, a pesticide should only be used after determining that other economic alternatives are not feasible, and after assessing the potential environmental impact of that particular pesticide.

SUSTAINABLE AGRICULTURE RESEARCH EFFORTS AND PROJECTS AT THE U. OF M.

R. Kent Crookston, Director of Sustainable Ag., Dept. of Agronomy, U.of M., Saint Paul, 55108.

Since the formation of the U. of M. Sustainable Agriculture Program, a variety of projects focused on agricultural sustainability have been initiated or identified. Probably the most prominent of these is the "Koch Farm" which the University established in 1988. This farm (named after the previous owner) had been maintained as a minimum-input farm for the previous 35 years. During this time no insecticides had been used and herbicide use was minimal. Fertilizer application (commercial or natural) had been light, and soil fertility was at "native" levels (same as original prairie). The farm had not been tile drained and did not appear to have ever been deep-cultivated.

The farm is located immediately adjacent to the Southwest Experiment Station at Lamberton and is an ideal site for sustainable agricultural research. For example, farmers and scientists have very little data on, or management experience with, organic sources of phosphorus (P). Experiment stations across the country, as well as virtually all farms in the U.S., have been built to "sufficiency levels" of both P and K. Even if fertilizer applications to these soils ceased today, most could be farmed for 20 years before native levels of P and K would return. Koch farm research can thus begin immediately to investigate techniques for, and effects of, reducing inputs of external fertilizers. The farm is also ideally suited for research on low-energy tillage, low (or zero) use of pesticides, and interaction of drainage with within-soil movement of pesticides.

The farm is presently divided into five main parcels (see diagram, next page).

Parcel 1. Approximately 40 acres established according to experimental design and maintained under four management regimes: organic, lower input, higher input, and zero input. Each will be managed independently of the other; any one management step can be altered at any time.

organic. No chemical applications; use of manures, mechanical weed control, etc. The best regional organic practices will be implemented so that crops grown on these plots will qualify as "certified organic."
lower input. Chemical applications will be minimized, fertilizers will be banded, post-emergent herbicides (if needed) will be banded and combined with mechanical weed control, insecticides will be used only on a prescription basis.
higher input. Chemical applications will not necessarily be minimized. Broadcast fertilizer and pre-emergent herbicides will not be avoided. Insecticides will be used according to current industry recommendations, etc.
zero input. Half of this parcel will be cropped as in the other management options; half will be established and kept as native prairie. There will be no inputs other than those needed for maintenance (mechanical and manual weed control of the cropped area, occasional prairie burning, etc.). This parcel will serve as a reference base and will allow unique ecological investigations.

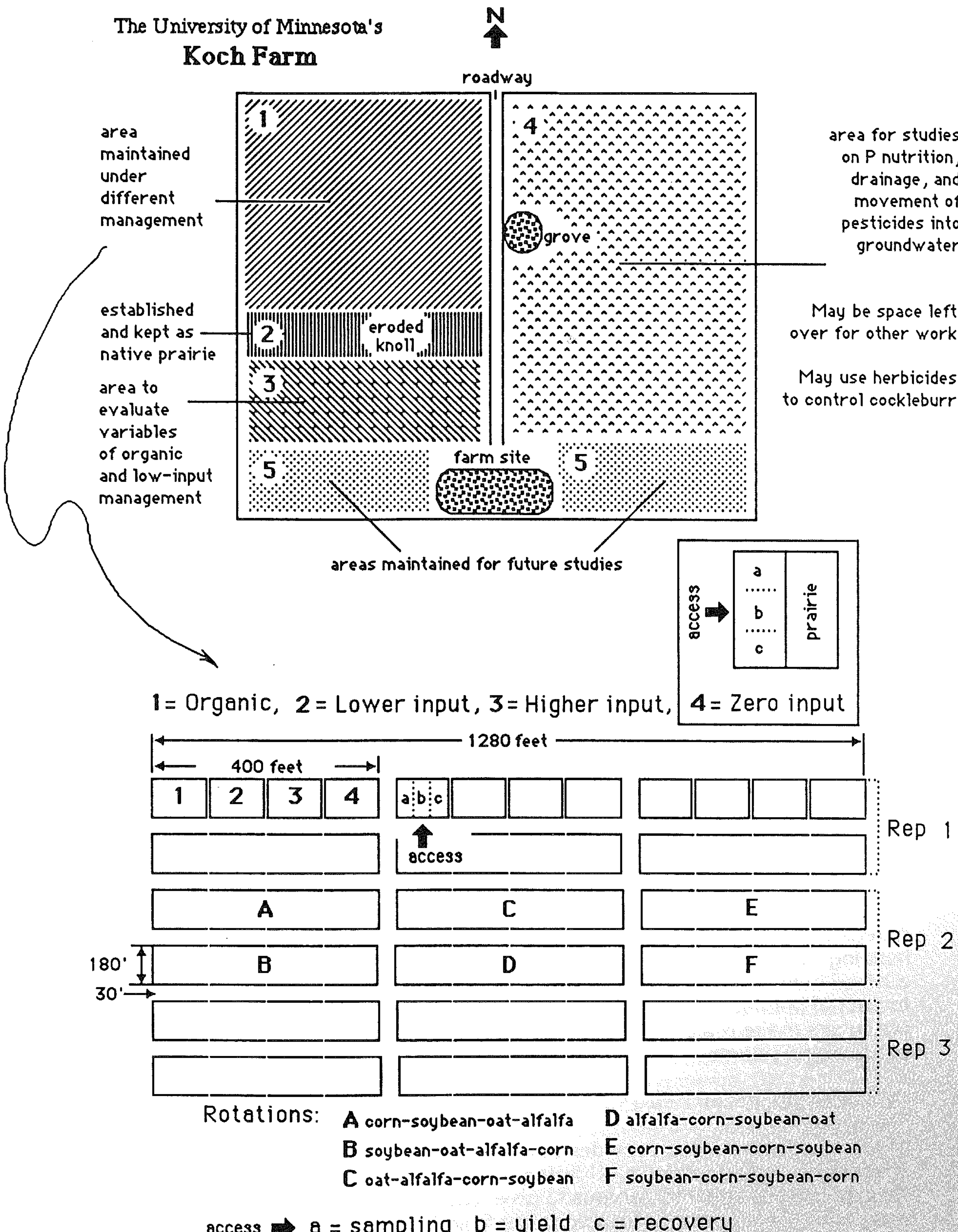
Two rotation systems will be maintained across the management options. The first will be a corn:soybean:oat: alfalfa rotation; the second will be the locally-popular corn:soybean rotation. Access to each experimental block will be controlled. One third of the block will be made available for sampling (soil probes, insect sweeps, plant sampling, etc); one third will be used for yields, one third will be set aside for "recovery." After three years, the recovery portion will become the yield portion, the yield portion will become the sample portion, and the sample portion will become the recovery portion. That way, all parts of the study will always remain accessible to even destructive sampling.

Parcel 2. Approximately 10 acres of native prairie maintained in an area that contains the most extreme soil types on the farm. This area will be used for a variety of ecological studies.

Parcel 3. A 30-acre area used to investigate variables of the organic and/or low input approach. Results from this part of the farm will likely result in modifications of management of parcel # 1.

Parcel 4. A 60-acre area used to study organic phosphorus nutrition, and the effects of drainage on movement of fertilizers and pesticides through the soil. Because of a severe cockleburr problem on this part of the farm, chemicals will be used to bring the field into research-acceptable condition.

Parcel 5. Approximately 30 acres maintained for future studies.


The University of Minnesota's
Koch Farm
N
roadway
1
4
area maintained under different management
area for studies on P nutrition, drainage, and movement of pesticides into groundwater
grove
established and kept as native prairie
2
eroded knoll
May be space left over for other work
May use herbicides to control cockleburr
3
area to evaluate variables of organic and low-input management
5
farm site
5
areas maintained for future studies
a
b
c
access
prairie
1 = Organic, 2 = Lower input, 3 = Higher input, 4 = Zero input
1280 feet
400 feet
1
2
3
4
a b c
access
Rep 1
A
C
E
Rep 2
180'
30'
B
D
F
Rep 3
Rotations:
A corn-soybean-oat-alfalfa
B soybean-oat-alfalfa-corn
C oat-alfalfa-corn-soybean
D alfalfa-corn-soybean-oat
E corn-soybean-corn-soybean
F soybean-corn-soybean-corn
access a = sampling b = yield c = recovery

SUMMARY OF MINNESOTA EXTENSION SERVICE WATER QUALITY EDUCATION PROGRAMS. James L. Anderson, Department of Soil Science, University of Minnesota and Director, Center for Agricultural Impacts on Water Quality, St. Paul, MN 55108.

The Minnesota Extension Service (MES) has made a major commitment to developing educational programs in water quality. Some of its long-established educational programs in agriculture, home economics and natural resources have incorporated significant water quality components. MES is committed to examining all areas of its educational programs and incorporating information about the potential effects of management practices on water quality.

In 1987, an issue team was formed to evaluate MES water quality programs. The team consisted of members from all MES program areas representing staff with state, area and county responsibilities. The Water Quality Assessment Report was completed in March, 1988. Three priority sub-issue areas were identified for MES to devote staff time and resources. These priority areas are:

--waste management and utilization
--safe drinking water for families and communities
--agricultural practices affecting water quality

Waste Management and Utilization

1. *On-site sewage treatment workshops: cooperative efforts between the Minnesota Extension Service and the Minnesota Pollution Control Agency (MPCA).*

   Since 1980, more than 2,000 persons have been trained and have passed an examination in these workshops. Resource people from MPCA and MES present in-depth training for individuals who install sewage treatment systems, inspectors, site evaluators, designers, and pumpers. Extensive educational materials have been developed to assist these people. Intensive three-day basic workshops are held each year in several different locations, and three-day recertification workshops are held in two locations. In 1989 more than 825 people participated in basic and recertification workshops.

2. *Animal manure management programs*

   Extension agents and specialists have held many educational programs on building new and/or remodelled manure handling systems. They have also advised individual farmers on alternative designs that minimize the negative impact of animal manure on water quality. This effort is aimed at helping producers make maximum use of animal manure for plant and crop production systems.

3. *"Waste Management News"*

   This monthly newsletter provides background information for agents, specialists, and researchers. Utilizing existing money, Extension transferred an experienced agent to campus to give leadership to waste management programs. This person is located in the Soil Science Department. Assistance is being provided to local county government units with waste management information.

4. *Research on waste management*

Extension is taking the lead to seek out research on waste management from departments throughout the University of Minnesota. This research information will then be provided to individuals, governmental units, and others concerned with waste management problems.

Safe Drinking Water for Families and Communities

1. *Cooperative study of household water quality management*

The purpose of the study was to evaluate user satisfaction and educational needs pertaining to the use of selected water treatment devices to improve the quality of drinking water under a range of water quality and home installation operation conditions. Reverse osmosis treatment devices were selected as the type of system for evaluation. A total of 76 households in Brown and Nicollet counties were interviewed about their household water management and concerns about water quality.

2. *Well sealing demonstrations*

How to properly abandon and seal wells is an important issue to be addressed by local governments. Workshops and demonstrations have been conducted to educate individuals on proper sealing techniques. These demonstrations have been conducted in cooperation with well drillers and other state and local agencies.

Agricultural Practices Affecting Water Quality

1. *Anoka Sandplain Demonstration Project*

A cooperative project between the MES, Soil Conservation Service (SCS) and Agricultural Stabilization and Conservation Service (ASCS). Specific objectives are 1) to assist growers in adopting sound nitrogen management practices; 2) to assist growers in improving their water management; 3) to test an integrated "best management practices" approach to select pest control practices; and 4) assess whole farm activities and their potential to contaminate ground water.

2. *Non-point Source Hydrologic Unit Project*

A cooperative effort between ES and SCS in cooperation with other state, federal, and local agencies. Objectives are 1) utilize the farmstead assessment program to identify potential pollution activities; 2) develop conservation plans and provide technical assistance to growers; 3) implement plans to protect the ground water resources; 4) test available computer models; and 5) work to increase the awareness of all area residents on the importance of conservation.

AGRICULTURE AND WATER QUALITY: BEST MANAGEMENT PRACTICES FOR MINNESOTA. John C. Brach, Soil Conservation Service, St. Paul, MN 55101

In order to provide information on Best Management Practices (BMP's), the Minnesota Pollution Control Agency developed BMP handbooks for agriculture, urban, and forest land uses. A coordinating committee guided the development of the AGricultural Handbook by recommending the audience and overall goal, by providing technical assistance, and by reviewing the document.

The handbook was written for the layman and strives to explain why BMP's are needed, how to select them, their effectiveness and limitations, trade-offs involved, and where to go for more information. In the BMP selection discussion, two approaches are discussed. The first is to protect existing water quality and the second is to improve water quality where a problem already exists. The process used for selection is different for the two cases.

The use of combinations of practices or "systems" to make up a BMP is stressed. An example illustrates such a system and demonstrates that there is more to water quality improvement than controlling soil erosion.

The various practices are described along with a discussion of water quality benefits and a photograph for each one. The reader is also advised of sources of additional assistance that are available for each practice.

This handbook has been used by Soil and Water Conservation Districts, Watershed Districts, the Minnesota Pollution Control Agency, the Soil Conservation Service, and others in their information and education efforts. Quantity orders have also been received from colleges who are using it as a teaching resource.

Copies of "Agriculture and Water Quality: Best Management Practices for Minnesota" are available from the MPCA Division of Water Quality, 520 Lafayette Road, St. Paul, MN 55155.

SOIL CONSERVATION SERVICE PEST AND NUTRIENT MANAGEMENT STANDARDS AND SPECIFICATIONS. David D. Breitbach, USDA Soil Conservation Service, St. Paul, MN 55101.

The Soil Conservation Service (SCS) as an agency of the United States Department of Agriculture (USDA) has provided technical assistance to landusers with natural resource problems for more than fifty years. This technical assistance is delivered by field staff located in each county through the local Soil and WAter Conservation District (SWCD). Historically the emphasis of SCS activities was on soil erosion control and therefore the primary purpose of conservation practice standards and specifications wa to achieve a measure of erosion control.

During the past two decades SCS has promoted the concept of landusers planning and applying Resource Management Systems which include components of managing water supplies and agricultural chemicals (fertilizers and pesticides) along with soil erosion control. Recent initiatives by USDA directed at nonpoint source pollution control include helping farm operators better manage chemical inputs to reduce the problems of nitrates, phosphorous and pesticides in water supplies. In 1988 SCS contracted with the University of Minnesota to develop a handbook that would summarize what is currently in the literature relative to agricultural chemicals and water quality, to assess existing SCS conservation practice standards on how they address chemical use and water quality and to assist five states located throughout the nation to develop prototype nutrient management and pest management conservation practice standards. This project was completed in July 1989.

Minnesota was one of the five states selected to develop prototype standards. During development of these new standards SCS worked closely with University of Minnesota Extension Specialists (MES) from Soil, Agronomy, Entomology and Plant Pathology as well as the Minnesota Department of Agriculture and the Minnesota Pollution Control AGency. The resulting standards and specification "Nutrient Management" and "Pest Management" will be placed in the Soil Conservation Service Field Office Technical Guide to be used by field staff of SCS and SWCD's to plan and apply Resource Management Systems which will include greater emphasis on water quality concerns.

Nutrient Management is "Managing the amount, form, placement and timing of application of plant nutrients" with a purpose "To supply plant nutrients for optimum forage and crop yields, minimize entry of nutrients to surface and ground water, and to maintain or improve chemical and biological condition of the soil". The practice emphasizes considering all sources of nutrients (soil, legume, organic waste, and fertilizer); using soil test results; setting realistic yield goals; managing method and timing of nutrient applications; safe handling and storage of fertilizer materials; along with equipment maintenance and calibration.

Pest Management is "Managing agricultural pest infestations (including weeds, insects, and disease) to reduce adverse effects on plant growth, crop production and environmental resources" with a purpose "To develop a pest management program consistent with selected crop production goals that is environmentally acceptable". This practice emphasizes applying the principles of Integrated Pest Management and consideration of biological, cultural and mechanical as well as chemical control measures. The standard also contains information relative to the potential for pesticides to move by leaching and surface runoff along with ratings by soil map unit of the potential for leaching and surface runoff to occur. With this information SCS, SWCD, and MES field staff can better assist farm operators in planning pest control programs. Once the decision is made to use a pesticide the relative risk for leaching and surface runoff can be assessed.

These practice standards do not answer all of the questions nor will they solve all of the water quality problems. As more information is available on the vulnerability of water resources and pest control technology develops these conservation practice standards will be revised to provide federal, state and local agency field staff with improved resources to deal with water quality issues.

SECTION 3: A. **Atmospheric Contaminants and Lakes**: Governors IV; Organizer: S.J. Eisenreich, Dept. of Civil & Mineral Engineering, Univ. of MN

1:20 Opening remarks: S. Eisenreich

1:30 R. Strassman, Air Quality Division, Pollution Control Agency, St. Paul. *Acid precipitation in Minnesota - 10 years later.*

1:55 P.L. Brezonik, Dept. of Civil & Mineral Engineering, Univ. of MN, and D. Helwig, Air Quality Division, Pollution Control Agency. *Atmospheric deposition of mercury and its effects on Minnesota lakes.*

2:20 D. Swackhamer, Div. of Environ. & Occup. Health, Univ. of MN. *Atmospheric deposition of toxic organic chemicals to regional lake waters.*

2:45 P. Capel, U.S. Geological Survey, St. Paul. *Atmospheric deposition of herbicides in Minnesota.*

3:10 Refreshment Break

B. **Aquatic Weed Problems**; Organizer: G. Orning, Freshwater Foundation
A panel including weed experts from water management agencies, universities, and the private sector will discuss Minnesota's management plans for Eurasian water milfoil and other exotic weed problems in and reseach/information needs regarding these issues. (Abstracts not available for this panel.)

ACID PRECIPITATION IN MINNESOTA - 10 YEARS LATER.

Rick Strassman, Minnesota, Minnesota Pollution Control Agency, St. Paul, MN 55155

In 1982, the Minnesota Legislature passed the Acid Deposition Control Act which directed the Minnesota Pollution Control Agency to: a) Identify areas of the state containing sensitive resources, b) Adopt an acid deposition standard that applies in the sensitive areas, c) Establish a control plan to address both in-state and out-of-state sources, d) Ensure that all Minnesota sources subject to the control plan are in compliance by January 1, 1990.

Areas containing sensitive resources were mapped with the assistance of the State Planning Agency's Land Management Information Center. Computerized data bases of geographic information were combined with lake chemistry data and soil and peatland information to obtain a comprehensive map of resource sensitivity in Minnesota. Poorly buffered surface waters are located primarily in the northeast quadrant of the state in shallow soils over bedrock or in rolling moraine areas. Low base status soils are concentrated in the northern and eastern tip of the state where they are shallow to bedrock, and in sandy outwash plains in east central Minnesota.

Research indicated that terrestrial ecosystems in Minnesota, such as forests, peatlands, and croplands, are not as sensitive to acid deposition impacts as low alkalinity aquatic systems. A semi-empirical soil acidification model developed at the University of Minnesota was utilized to assess the sensitivity of non-agricultural soils. Results indicated only minor chemical changes in the most sensitive soils. In contrast, computer assessments of sensitive low alkalinity lakes indicated a significant potential for change in chemistry if acid deposition were to increase markedly in the state. MPCA staff determined that a standard should be set at a level that would be protective of the most sensitive lakes in the state.

Agency staff conducted an extensive literature survey and reviewed the work and recommendations of Scandinavian and Canadian officials. This empirical work indicated that an average annual precipitation pH of 4.6-4.7 is necessary to prevent lakes with alkalinities less than 40 microequivalents per liter (ueq/l) from acidifying. This conclusion is supported by other dose/response work conducted in the upper Midwest. Mathematical modeling also indicated that a precipitation pH of 4.7 would be adequate to protect sensitive lakes from long-term acidification.

A non-linear regression equation relating sulfate and hydrogen ion concentration in precipitation was utilized to relate precipitation pH 4.7 to sulfate deposition. In Minnesota, a precipitation pH of 4.7 is associated with 11 kg/ha wet sulfate deposition, assuming 70 centimeters (cm) of precipitation each year. Minnesota's standard is based on non-degradation of the resource and is geared to maintaining the present chemistry and biology of the sensitive lakes.

Two transport models (ESEERCO and MESOPUFF II) were used to determine the source of sulfur dioxide emissions ultimately impacting acid sensitive regions in Minnesota. Results were used to design a control plan to ensure compliance with the deposition standard. Based on the modeling results, using 1980 emissions and meteorological data, Minnesota emissions contributed about 22% of the total sulfur deposition in the state when averaged across six (6) receptor sites. Out-of-state sources contributed approximately 78% of the deposition. Contribution of out-of-state sources to deposition at individual receptors ranges from 65-95%. For example, at the Sandstone site, Minnesota emissions contributed 8% of the total deposition, while out-of-state sources contributed 92% of the deposition, and only Texas exceeded 10% of the total wet contribution. No one source or region dominated deposition.

The extremely low culpabilities dictated a more unconventional approach in formulating an acid deposition control plan. A National approach to emission reductions is necessary to minimize the acid rain problem in the state and to attain and maintain the 11 kg/ha per year wet sulfate deposition standard. In order for Minnesota to lobby for a national acid deposition control plan, the state must first prevent its emissions from adding to the acid rain problem in other states. With this objective in mind, the following goals were incorporated into the control plan:

a) prevent emissions from increasing significantly above existing levels;
b) commit now to implementing Minnesota's fair share under proposed national legislation;
c) require reasonably available control technology (RACT) on the largest SO_2 emitters.

Specifically, the Agency's control plan:

1) Places a cap on the emissions from Minnesota's two largest utilities;
2) Restricts emissions to a state-wide total of 194,000 tons per year SO_2 by 1994 (represents a 60,000 tons per year reduction from 1980 levels and approximates the reductions required of Minnesota under most national proposals);
3) Require reasonably available control technology on the two largest SO_2 emitters in the state, obtaining 50% and 20% reductions in SO_2 emissions from the respective power plants.

MERCURY IN NORTHERN MINNESOTA LAKES: HISTORICAL TRENDS AND POTENTIAL SOURCES. Patrick L. Brezonik, Dept. of Civil & Mineral Engrg, Univ. of MN, and Daniel D. Helwig, MN Pollution Control Agency, St. Paul.

High concentrations of mercury (Hg) in fish of some lakes and rivers in Minnesota were first noted in the early 1970s. Major point sources to certain Minnesota rivers, such as industrial discharges and sewage treatment plants, generally were identified and controlled during the 1970s, and Hg in fish from these rivers declined substantially. Sources of Hg to remote lakes in northeastern Minnesota have been more difficult to identify. In some cases, Hg burdens in gamefish taken from lakes with no apparent watershed sources of contamination exceed the federal standard for human consumption. Fish levels of Hg also are high enough in some lakes to be deleterious to fish-eating wildlife such as otters, osprey, eagles, and loons. Because of the lack of apparent anthropogenic sources of Hg to these lakes, a debate has arisen as to whether the problem is anthropogenic in origin or is the result of natural (geochemical) conditions.

This paper describes results of studies undertaken to answer several basic questions related to the above mentioned debate:

(1) Have Hg inputs to remote lakes in northeastern Minnesota changed over the time period of white settlement in the state (roughly since the mid-1800s)?

(2) What is the spatial variability of Hg inputs to these remote lakes?

(3) Is there evidence for anthropogenic sources of Hg in these lakes, and if so, can the source be identified?

Sediment cores taken from four remote lakes in NE Minnesota (Henning 1989) show that the Hg content of the sediments has increased by factors of about 3.4-3.9 since the mid-1800s. Sediment strata were dated by ^{210}Pb techniques, which allowed the timing of increases in Hg levels to be determined, along with actual rates of Hg accumulation in the sediments (ug m^{-2} yr^{-1}). Separate laboratory studies, along with information from the literature suggest that stratigraphic data on accumulation rates are a faithful representation of deposition rates to the sediments and, by inference, input rates to a lake from external sources. In general, mercury profiles for the sediment cores show that Hg concentrations began to increase slowly from relatively constant background levels (50-100 ng/g [dry wt]) after about 1860-90, and in most cases, a more rapid increase to levels of ~250 ng/g began between 1920 and 1950.

Modern deposition rates calculated from a large number of sediment cores taken from each lake were found to fall in a surprisingly narrow range: 18-26 ug m^{-2} yr^{-1}, in spite of the fact that the lakes differ in size, water chemistry and hydrologic status. The modern accumulation rates were estimated to be 3.2-3.6X those occurring in pre-settlement times. The uniformity of these results suggest that direct deposition onto lake surfaces from the atmosphere is responsible for much if not most of the Hg in the lakes, and the increases in modern time suggest that the majority of the Hg loading is the result of human activity.

Although precise figures are not available for atmospheric deposition of Hg in remote regions of North America, a reasonable estimate (e.g. Fitzgerald 1986) is about 15 ug m^{-2} yr^{-1}. Application of this estimate to the lakes in northeastern Minnesota leads to the conclusion that about 60-80% of the Hg in the lakes can be accounted for by direct atmospheric deposition. Moreover, a rather constant fraction of the Hg deposited on the terrestrial part of the lakes' watersheds is transported to the lakes. The difference between the mass accumulation rate of

Hg to the sediment and the rate of Hg deposition directly to the lake surface is divided by the total Hg loaded to the watershed is close to 10% for all four lakes with accurate estimates of Hg accumulation.

Comparison of recent analyses of museum specimens of northern pike and walleye collected in Minnesota during the 1930s and similar-sized specimens collected from the same lakes in the 1980s shows that body burdens of Hg have increased since the 1930s (Swain and Helwig 1989). The mean Hg content of the 1930s fish is 0.13 ug/g, while that for the 1980s fish is 0.31 ug/g ($p < 0.01$, $n = 12$). In addition, review of data on fish collected by the Minnesota DNR and PCA in since 1970 indicates that Hg body burdens have continued to increase. The data base has 14 lakes for which paired samples of similar-sized (50 cm long) northern pike are available for comparison. The number of years between sampling in a given lake ranged from 5 to 16 years, and the differences in Hg content were divided by the number of years between samples to obtain the rate of change in Hg content. A significant increase of about 0.017 ug/g per year was found (paired t-test, $p < 0.02$). Means for the two time periods were 0.36 and 0.47 ug/g, an average increase of 0.11 ug/g over an average of 7.2 years.

In spite of the fact that the major source of Hg to remote lakes in northeastern Minnesota is atmospheric deposition and input rates are fairly uniform, fish burdens of Hg vary widely among lakes. Thus, local factors apparently control the rates of Hg cycling and transformation to methylmercury forms that are found in fish. These factors include lake chemistry, which in turn is related to watershed geology. Mercury levels in fish are negatively correlated with lakewater alkalinity and positively correlated with the presence of organic color (aquatic humus). However, present information is insufficient to pinpoint cause-effect relationships. Our present understanding of the factors affecting Hg burdens in fish has been derived almost exclusively from statistical analyses of lake survey data. Controlled experiments under environmentally realistic conditions are needed to determine the environmental conditions that promote or retard methylation of Hg and its accumulation in gamefish.

References

Fitzgerald, W.F. 1986. Cycling of mercury between the atmosphere and oceans, pp. 363-408 in *The Role of Air-Sea Exchange in Geochemical Cycling*, P. Buat-Menard, Ed., D. Reidel Publ., Boston.

Henning, T.A. 1989. Historical and areal deposition of mercury in NE Minnesota and northern Wisconsin lakes. M.S. thesis, Univ. of Minnesota, Minneapolis.

Swain, E.B. and D.D. Helwig. 1989. Mercury in fish from northeastern Minnesota lakes: historical trends, environmental correlates, and potential sources. *J. Minnesota Acad. Sci.* **55**: 103-109.

We gratefully acknowledge the contributions of Dan Engstrom, Tom Henning and Ed Swain in this study. Work described in this paper was supported by the Legislative Commission on Minnesota Resources, the Water Resources Research Institutes Program, and the State of Minnesota.

ATMOSPHERIC DEPOSITION OF TOXIC ORGANIC CHEMICALS TO REGIONAL LAKE WATERS. Deborah L. Swackhamer, Division of Environmental and Occupational Health, School of Public Health, University of Minnesota, Minneapolis, MN, 55455.

A wide variety of toxic organic compounds are found in the atmosphere as a result of direct point source emissions, fugitive emissions, and volatilization. Many of these compounds are resistant to degradative processes and are not efficiently removed from the atmosphere by physical processes, thus leading to long atmospheric residence times and transport to regions far from their source. A typical example would be the polychlorinated biphenyls (PCBs), which are found throughout the global ecosystem, including the arctic and antarctic. Other compounds of interest include polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-p-dioxins (PCDDs) and furans (PCDFs), lindane (BHC), hexachlorobenzene (HCB), toxaphene, and DDT.

Toxic organic contaminants exist in the atmosphere in the gas phase and associated with particulate aerosols. The partitioning between phases is a function of the temperature, the concentration of total suspended particulates in the atmosphere, the available surface area of those particulates, and the compound's vapor pressure. With the exception of the higher molecular weight of PAHs, PCBs, PCDDs and PCDFs, most of the above-mentioned compounds exist predominantly in the vapor phase.

Precipitation events, dry fallout, and vapor exchange from air to water all serve to remove airborne contaminants to lakes. Particle-associated contaminants are deposited to water surfaces by gravitational settling and Brownian motion. They are thought to be associated with submicron-sized particles, having deposition velocities of 0.1 - 0.9 cm/sec. Gas phase contaminants will partition into water as a function of their Henry's Law constant, the temperature at the air-water interface, the concentration gradient between the two phases, and the overall liquid or gas phase mass transfer coefficient. Precipitation by either rain or snow can remove contaminants from the atmosphere by the partitioning of gas phase contaminants into raindrops or by the incorporation or scavenging of particles by washout.

Data on the deposition of toxic organic contaminants is relatively scarce. Studies have been done on the atmosphere over the upper Great Lakes, rural Wisconsin, and rural Minnesota, mostly for PCBs and PAHs. Several of these studies employed a mass balance paradigm to determine the relative importance of atmospheric deposition to the chemical burden in the lake, compared to other sources. Approximately half of the PCBs in Lake Michigan are due to atmospheric deposition, while more than 90% of the PCBs in Lake Superior and remote lakes is from the atmosphere. For most compounds, scavenging of particles by precipitation is the dominant depositional process. The mass balance studies have determined that, on an annual basis, the net vapor exchange is from water to air, making the atmosphere a sink as well as a source for toxic organic compounds. It is likely that significant dynamic cycling of contaminants occurs between air and water, dominated by water-to-air transfer in summer, and episodic removal from the atmosphere during discrete precipitation events.

ATMOSPHERIC DEPOSITION OF HERBICIDES IN MINNESOTA. Paul D. Capel, United States Geological Survey, Water Resources Division, St. Paul, MN 55101

Anthropogenic organic chemicals are transported long distances through the atmosphere and deposited on aquatic and terrestrial ecosystems through wet and dry processes. Atmospheric transport is an important component in the overall behavior of many organic environmental contaminants. Previous studies have shown that numerous herbicides are present in the atmosphere and in rain and fog. The herbicides can enter the atmosphere during application and through volatilization and wind blown particles.

The concentrations of triazine herbicides (atrazine and its metabolites, and simazine and propazine) have been quantified in rain and snow events during 1989 in St. Paul, Minnesota. Weekly integrated rain samples from Ely, Minnesota, and northern Iowa also have been analyzed for these same herbicides. Atrazine concentrations in rain during spring application were about 10 ug/L (micrograms per liter). These concentrations decreased quickly during the following months. Typical concentrations of atrazine in rain were about 0.1 to 0.5 ug/L. When the typical concentrations of atrazine in rain are multiplied by normal statewide precipitation (50 to 75 centimeters per year), an estimated 0.5 to 3.3 grams per hectare per year could be deposited on Minnesota. If a mean deposition value of 1.3 grams per hectare per year is assumed, then atmospheric deposition to Minnesota's surface waters is on the order of 5 Mg (megagrams) of atrazine per year, two-fifths of this is to lakes and reservoirs and three-fifths is to wetlands. Although this is only about 0.4 percent of the total agricultural application of atrazine (estimated atrazine use in Minnesota was 1300 Mg in 1984), the atmospherically deposited atrazine potentially could have a deleterious effect on the surface water ecosystems.

SECTION 4. Surface and Groundwater Monitoring in Minnesota: Governors V; Organizers: T. Scherkenbach, MN Pollution Control Agency, and W.J. Herb, U.S. Geological Survey

1:20 Opening remarks: T. Scherkenbach and W.J. Herb

1:30 W.J. Herb, Water Resources Division, U.S. Geol. Survey, St. Paul. *The U.S. Geological Survey's surface-water monitoring network in Minnesota.*

1:55 K. Svanda, Water Quality Div., MN Pollution Control Agency, St. Paul. *Water quality monitoring in Minnesota -- trends from the past and strategies for the future.*

2:20 S.R. Maeder, State Planning Agency, St. Paul. *Water quality and quantity data management.*

2:45 J.T. Hatch, Bell Museum of Natural History, Univ. of MN, Minneapolis and P.A. Bailey, MN Pollution Control Agency, St. Paul. *Fish community assessment as a water resource monitoring tool in Minnesota.*

3:10 Refreshment Break

3:30 T.J. Larson, Div. of Water Quality, MN Pollution Control Agency, St. Paul. *Minnesota River Assessment Project (MRAP) - A basin wide approach to water quality protection.*

3:55 L.D. Reeves, Div. of Waters, MN Dept. of Natural Resources, St. Paul. *DNR/USGS Observation Well Network.*

4:20 Discussion and Questions

THE U.S. GEOLOGICAL SURVEY'S SURFACE-WATER MONITORING NETWORK IN MINNESOTA.
William J. Herb, U.S. Geological Survey, St. Paul, MN 55101

The Water Resources Division (WRD) of the U.S. Geological Survey (USGS) operates a network of more than 200 surface-water (SW) stations in Minnesota. This network, in one form or another, has been in place since about 1900. The USGS, one of the bureaus within the Department of Interior, comprises 5 divisions. The Administrative and Information Systems Divisions support the activities of the three "action" divisions. The Geologic Division does most of the geologic work of the USGS and the National Mapping Division is best known for its production of the standard 7-1/2 minute topographic quadrangle maps. The largest and least well known of the action divisions, the WRD, comprises more than 4,000 personnel, and has offices in every state.

The WRD is organized into a headquarters office, four regions, and 43 District offices. Each district generally coincides with a State, but there are several multi-state districts. The Northeastern Region, which includes Minnesota, comprises 19 states and 12 districts. The WRD has 8 missions:

1. Hydrologic data collection
2. Hydrologic investigations
3. Hydrologic research
4. Hydrologic hazard data acquisition
5. Coordination of Federal water-data collection
6. Hydrologic data dissemination
7. Scientific and technical assistance
8. Water Resources Research Act administration.

The operation of a SW data network falls clearly under the first mission. The largest part of the SW network in terms of effort is the operation of continuous-record streamflow stations, where stream stage is recorded at intervals of 1 hour or less. Stage data, combined with measurements of discharge, are used to compute the amount of water flowing in a stream.

The WRD normally recognizes eight use classes for the data collected at continuous-record gaging stations (Winterstein and Arntson, 1989):

1. Regional Hydrology Stations--data collected at these stations are used to develop regionally transferrable information about the relationships among basin and streamflow characteristics.

2. Hydrologic Systems Stations--data collected at these stations are used to define hydrologic conditions and the sources, sinks, and transport of water through both regulated and unregulated systems.

3. Legal Obligation Stations--data collected at these stations provide records of flow for verification or enforcement of treaties, compacts, and decrees.

4. Planning and Design Stations--data collected at these stations are used for the planning and design of a specific water project (for example, a dam, levee, or floodwall) or for a group of structures.

5. Project Operation Stations--data collected at these stations are used to assist water managers in making operational decisions such as reservoir releases, hydropower operation, or diversion.

6. Hydrologic Forcast Stations--data collected at these stations are regularly used for developing such things as flood forcasts or flow-volume forcasts.

7. Water-Quality Monitoring Stations--data collected at these stations are used in combination with water-quality data to determine loads of various water-quality constituents such as sediment or chemicals.

8. Research Stations--data collected at these stations are used for a particular research project or water-resources investigation.

Continuous-record gaging stations in Minnesota serve an average of 2.3 purposes (Winterstein and Arntson, 1989).

Most of the WRD's SW monitoring program is determined by local needs. About 50 percent of the SW monitoring program is part of the Federal-State Cooperative Program in which the WRD shares up to 50 percent of the cost of operation of a stream-gaging station. An additional 25 percent of the SW monitoring program is in response to the local needs of other Federal agencies such as the U.S. Army Corps of Engineers (COE). The other 25 percent of the SW monitoring program is in support of WRD national program priorities.

In terms of the total number of stations funded, the Minnesota Department of Transportation (DOT) is the largest cooperator in the WRD program, followed by the COE, and the Minnesota Department of Natural Resources (DNR). Many stations are funded from multiple sources.

The COE provided more than $393,000 to the WRD SW monitoring program in 1989. The USGS provided about $243,000 in the cooperative and Federal programs, and DNR and the International Joint Commission provided about $95,000 each. DOT provided an additional $73,000, and other agencies provided a total of about $90,000. A primary characteristic of the WRD SW monitoring program is its broad base of support.

REFERENCES

Winterstein, T.A. and Arntson, Allan D., 1989, Cost effectiveness of the streamflow-gaging program in Minnesota: U.S. Geological Survey Water-Resources Investigations Report 88-4129, 96p.

WATER QUALITY MONITORING IN MINNESOTA - TRENDS FROM THE PAST AND STRATEGIES FOR THE FUTURE. Kathy Svanda, Water Quality Division, Minnesota Pollution Control Agency, 520 Lafayette Road, St. Paul, Minnesota 55155.

Minnesota is a state rich in water resources with nearly 92,000 miles of streams and over 12,000 lakes covering 3.4 million acres. Most of the state's boarders are actually water, and three of the major continental drainage basins have headwaters in Minnesota. Surface water leaving Minnesota flows in three directions; east through the Lake Superior Basin to the Great Lakes and the Atlantic Ocean, south through the Mississippi and Missouri basins to the Gulf of Mexico, and north through the Red River and Lake of the Woods basins to Hudson Bay. The geography of the state is dominated by water.

The size of Minnesota's water resource and the important part which water plays in the state's economy have helped determine how the resource is managed in Minnesota. Several state departments and agencies have legal authority and jurisdiction over specific programs that deal with surface water. The Minnesota Department of Health addresses public health concerns and has jurisdiction over drinking water supplies. The Minnesota Department of Natural Resources has jurisdiction over water levels, water use appropriations, recreational use of waters, fish and wildlife concerns, and shoreline and state park management. The Minnesota Pollution Control Agency has jurisdiction over pollution related issues. This includes monitoring the waters of the state to assess the levels of pollution and determining the sources of pollution. It also includes controlling pollution. Local units of government (counties, municipalities, watershed districts, soil and water conservation districts, etc.) can exercise authority over the resource through shoreline use regulations, zoning, and permitting activities. Of course, there are also federal agencies which have jurisdiction over water resources in Minnesota, including the United States Geological Survey and the Corps of Engineers.

Each of these agencies needs information about the resource in order to effectively manage water in Minnesota. Each group which has jurisdiction over water in the state has designed and operated monitoring programs that furnish the kind of data necessary to help them accomplish their legislative mandates and program goals. As an example, the Minnesota Pollution Control Agency conducts a variety of monitoring programs under the authorities granted by federal and state legislation. These monitoring programs collect and evaluate data which define the water quality of the state. The data are used to identify pollution, assess control programs, enforce environmental regulations, and report the changes in the state's water quality.

Historically, every agency did what they were required to do and conducted monitoring programs which helped them meet those requirements. This usually meant that sampling sites and frequency of collection, as well as the parameters analyzed, were dictated by the needs of the the individual group doing the monitoring. There were some cooperative monitoring programs, but these were generally site specific and the result of major quality or quantity problems. Most groups had the jurisdiction and the budgets to allow them to conduct the monitoring programs which they felt were necessary. For example, The Minnesota Pollution Control Agency operated an ambient stream monitoring network in the early 1970's that consisted of 125 monitoring sites state-wide. Each site was monitored monthly for 45 parameters, using the analytical technology that was available at that time.

In the mid 1970's, this MPCA ambient monitoring program changed. Decreases in both federal and state funding, as well as increases in analytical and operational costs, forced a reduction in the monitoring program. The number of sites monitored decreased from 125 to 55. Monitoring was conducted during nine months of the year instead of twelve, and the number of parameters dropped from 45 to 20 at each station. Most state and federal agencies involved in water monitoring experienced budget cuts during this period and were forced to also reduce their monitoring efforts. Like everything else, water quality monitoring in Minnesota was affected by rising inflation and reduced or lost funding sources.

The decrease in funding for monitoring programs has continued during the last ten years. Although this has resulted in a smaller amount of water quality and quantity information being collected throughout the state, it has fostered more coordination between agencies "to try and get the most for the monitoring dollar." There has been good cooperation among state agencies and between state and federal agencies. The last ten years have also seen changes in monitoring and analytical technology. Although this has tended to increase the costs, new technology has allowed us to more accurately collect information and identify sources of pollution such as toxics.

Agencies conducting water quality monitoring in Minnesota recognize both the need to coordinate their efforts and to utilize current technology. In the future, there will be more coordination between state and federal agencies and local groups. Much of this "shared monitoring" will be the result of the local water planning effort and the development of county water management plans. The development of the State Water Management Plan, currently occurring under the direction of the Environmental Quality Board and the State Planning Agency, should result in a blueprint for this effort.

Everyone involved in monitoring will see more emphasis placed on the identification and control of toxics, not only in the water column, but throughout the aquatic environment. The control of nonpoint source pollution in both urban and rural areas will also play an important part in determining what kinds of monitoring will be done. The relationship between surface and ground water quality in the state will be better understood, and the impact of air quality and deposition on water will be defined, particularly in regard to toxics. There will be more use of biological monitoring and biological indicators to better understand the effects of pollution and to evaluate control programs. And there will probably technological developments that will change the way we monitor and evaluate Minnesota's water quality.

WATER QUALITY AND QUANTITY DATA MANAGEMENT

Susanne R. Maeder, Minnesota State Planning Agency, Land Management Information Center, 300 Centennial Bldg., 658 Cedar St., St. Paul, MN.

Effective water resources management requires good information. Information is expensive to collect; generally, state agencies need more data than they can afford. Therefore we need to make the most efficient use of any data that we collect. Water resources management programs in Minnesota are dispersed among several state agencies, and among federal, state, and local agencies. Data collected to support these management programs are similarly dispersed. This makes it a challenge to practice good data management.

There are a number of ways in which Minnesota agencies promote good water information management:

Coordination of data base development, through the inter-agency "Systems for Water Information Management" (SWIM) water data advisory group, to maintain compatibility among data bases.

Identification of data guidelines, in the areas of common resource numbering, coding, and geographic referencing.

Recommendations for "designated data repositories," -- data bases where certain types of information should reside - in the interests of consolidating data collected by different agencies.

Integration of individual data collections into larger data bases for ease of access (e.g., in the ground water area, MPCA's Integrated Ground Water Information System and SPA's Ground Water Clearinghouse).

Use of the Geographic Information System (GIS) as the framework for integrating tabular water data collections with other natural resource data.

A number of activities supported by the Minnesota Ground Water Protection act of 1989 will improve the state's overall water data management. A State Water Monitoring Plan is under development. This plan will include recommendations on data management, and development of an automated index of monitoring stations to improve monitoring coordination. The Ground Water Act also requires strengthened water data compatibility standards to be developed by the Environmental Quality Board. Expanded monitoring, and construction of integrated ground water data bases, have been funded under the bill.

Local groups are becoming more active in water data collection, whether through Comprehensive Local Water Planning activity at the county level, lake improvement associations, or watershed districts. Information collected by these groups can only become useful to a wider audience if it can be channeled to generally accessible state data bases. PC-compatible software has been distributed by state agencies to local entities to enable them to input, manipulate, and transmit ground water and lake level data in a state-compatible format. This type of state/local cooperation in data collection has been successful and needs to be expanded.

The Geographic Information System is the ultimate framework for integrating all natural resource information. All information relating to water quality, water levels, water flow, point pollution sources, to name just a few, can be combined with ancillary information on land use, soils, topography, geology, and drainage which is necessary to fully analyze water resources problems. This integration can be effected by proper georeferencing of any water information Systems Consortium, another inter-agency group, is working to improve data management and communication in this area.

FISH COMMUNITY ASSESSMENT AS A WATER RESOURCE MONITORING TOOL IN MINNESOTA. Jay T. Hatch, Gen. College/Bell Mus. Nat. Hist., Univ. of MN, Mpls., MN 55455, and Patricia A. Bailey, MN Poll. Control Agency, St. Paul, MN 55155.

The purpose of this paper is to explain 1) why biological assessment needs to become a tool of water resource monitoring in Minnesota, 2) why fish community assessment is the most reasonable tool to use, 3) why we recommend Karr's Index of Biotic Integrity (IBI) as the instrument of fish community assessment, and 4) how we plan to develop IBI for use in Minnesota. Direct, systematic biological assessment currently is not a part of Minnesota's water resource monitoring program. Yet, the Clean Water Act calls for the restoration and maintenance of the biological as well as chemical and physical "integrity of the Nation's waters." At present in Minnesota, we rely upon the assumption that if chemical water quality standards are met, then biological integrity will be maintained. However, it makes more sense intuitively to measure biological integrity by directly evaluating the biota. Further, the water chemistry approach is not sensitive to impacts of habitat degradation resulting from nonchemical pollution.

A variety of aquatic species and community groups (e.g., diatoms, benthic macroinvertebrates) have been used as indicators of general water quality. Recently, however, fish have emerged as a particularly useful group in assessing overall biological integrity in aquatic ecosystems for several reasons. From the ecological standpoint, they represent all consumer trophic levels and so are functionally connected to other groups which are not directly monitored. Also, they are mobile, sensitive to changes in chemical and physical conditions, and have multiple-year life spans so that they have the potential to reflect both short-term and long-term environmental conditions. From a practical perspective, fish offer fewer identification difficulties and are less time-consuming and expensive to collect and process than other groups of organisms. Fish also are important and familiar to the general public, and much of the regulatory language regarding water use is aimed at protecting fish.

Although several methods for measuring fish community well-being have been developed or refined in the past few years, Karr's Index of Biotic Integrity (IBI) has received the most widespread use and critical investigation. Studies have shown that IBI is sensitive to many kinds of degradation and that it responds numerically even to small changes in environmental conditions. IBI has been effective in locating areas of impact from both point-source and, very importantly, nonpoint-source pollution. Finally, IBI appears to be a measure that exhibits reasonable reproducibility over space and time and whose variability can be characterized quantitatively and understood biologically.

Karr's IBI is comprised of 12 so-called metrics, six that measure attributes of species composition and richness, three that measure attributes of trophic composition, and three that measure attributes of fish abundance and condition (Table 1). To be able to compute and interpret IBI scores for a given geographic region, several preliminary determinations must be made. First, standard sampling protocols that govern site selection, gear type used, sampling effort, and sample processing under different stream conditions need to be established. Species to be included in metrics 5-9 and anomalies to be included in metric 12 must be identified. In our opinion, the kinds of hybrids to be recognized in metric 11 also must be worked out or the metric cannot be applied in a standard fashion (our present intention is to delete this metric). Next, rating criteria for each metric must be established so that observed metric values can be converted to ratings of 5 (expected at least impacted or best possible sites in the area), 3 (expected at moderately impacted sites), or 1 (expected at strongly impacted sites) (see Table 1.) Metric values—especially those of metrics 1-5 and 10—will vary with stream size, gradient, and geographic region, and these factors must be taken into account when establishing rating criteria (e.g., Figure 1).

Once sampling protocols and metric rating criteria have been established, an IBI score for a site within the specified region can be computed by converting each measured metric value to its appropriate metric rating and then summing the ratings. All IBI scores will fall between 12 and 60. Based on the IBI score and the judgement of regionally knowledgeable biologists, the fish community can be assigned one of several integrity levels varying from very poor to excellent. For a given stream type in a given region, for example, IBI scores of 20-30 could indicate poor integrity, 31-42 fair integrity, 43-53 good integrity, and 54 or more excellent integrity.

We and other aquatic biologists from the Bell Museum, the Minnesota Pollution Control Agency and the Minnesota Department of Natural Resources are in the process of developing IBI for application in Minnesota's streams. At present, we are establishing sampling protocols and identifying species to be used in metrics 5-9. We also are using historical data from Bell Museum and DNR fish collections to establish metric rating criteria for different stream sizes and types in various geographic regions in the state.

Table 1. Fish community attributes, corresponding metrics proposed for Minnesota, and example scoring criteria based on data from the lower Sunrise River, Chisago County, MN. Modified from Karr *et al.*, 1986.

Community attribute	Metric	Metric rating criteria 5	3	1
Species composition and richness	1. Total no. of species	≥11	10-6	5-0
	2. No. of darter species	≥4	3-1	0
	3. No. of sunfish species	≥2	1	0
	4. No. of sucker species	≥2	1	0
	5. No. of intolerant species	≥3	2-1	0
	6. Proportion of individuals as tolerants (carp, white sucker and creek chub)[a]	<5%	5-20%	>20%
Trophic composition	7. Proportion of individuals as omnivores	<20%	20-45%	>45%
	8. Proportion of individuals as benthic insectivores[a]	>45%	45-20%	<20%
	9. Proportion of individuals as piscivores	>5%	5-1%	<1%
Abundance and condition	10. No. individuals per standard sample	>200	200-50	0-49
	11. deleted [Proportion of hybrids]	-	-	-
	12. Proportion of individuals with disease/tumor/ lesion/skeletal defects	0-1%	>1-5%	>5%

[a] modified from Karr's original metric

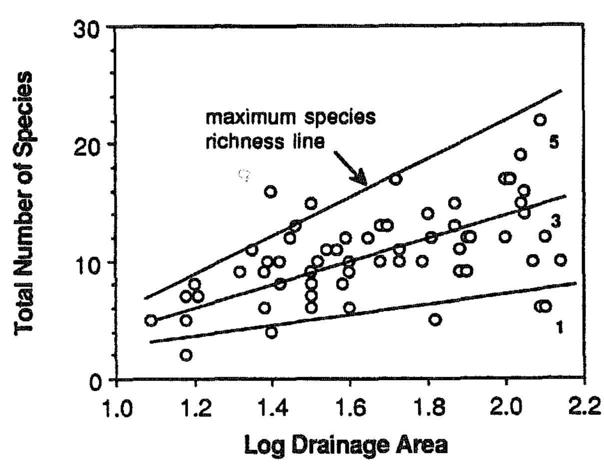


Figure 1. One example of how criteria for metric ratings (5, 3, 1) can be determined. Based on partial data collected from the Minnesota River drainage.

MINNESOTA RIVER ASSESSMENT PROJECT (MRAP) - A BASIN WIDE APPROACH TO WATER QUALITY PROTECTION. Timothy J. Larson, Minnesota Pollution Control Agency Division of Water Quality, St. Paul, MN 55155

The Minnesota River Basin is 16,770 sq. miles and drains all or parts of 37 counties in Minnesota. This represents approximately 18.5% of the land mass of the state. The most significant land use in the basin is cultivated land at 82%. The Minnesota Rivers average discharge into the Mississippi River increases the flow of the Mississippi by 47% and adds greatly to its pollutant load since the Minnesota River is the most highly impacted water body in Minnesota in regard to Nonpoint Source pollution (NPS). A Waste Load Allocation (WLA) for the Lower Minnesota River defined the water quality problem and the objective for improvement. The WLA predicted that a 40% reduction in organic BOD in the Minnesota at Shakopee is necessary to meet water quality limits in the lower Minnesota during critical conditions. To determine the feasibility of reaching the 40% reduction in organic BOD at Shakopee and for improving the water quality of the river and it's tributaries throughout the basin a comprehensive nonpoint source evaluation of the entire Minnesota system is necessary. A cooperative effort called the Minnesota River Assessment Project (MRAP) was established to carry out this evaluation. The Minnesota Legislature committed $700,000 for the first two years of this four year effort. Matching funds from the various cooperators have brought the total for the initial two years to $1.4 million. The study involves the MPCA, U.S. Geological Survey, U.S. Environmental Protection Agency - Environmental Research Laboratory in Duluth, South Central Minnesota Counties Water Planning Project, Mankato State University, Board of Water and Soil Resources, USDA Soil Conservation Service and Minnesota Department of Natural Resources with additional support from Metropolitan Waste Control Commission, Metropolitan Council, U.S. Corps of Engineers, and the University of Minnesota. The study has established a comprehensive monitoring network in the Minnesota River Basin, which will identify critical mainstream reaches and tributaries for estimation of the NPS load reductions necessary to achieve water quality goals, the amount of resources necessary to achieve those goals, and for the targeting of future water quality management programs. MRAP will demonstrate two processes for the state of Minnesota; the approach to be taken for determining NPS loading in a large watershed, and the ability of federal, state, and local units of government to work together toward a common goal. This project consists of three interrelated components which are essential in order to develop the information necessary to TARGET WATER QUALITY improvement and set WATER QUALITY GOALS for the Minnesota River Basin. This presentation will discuss those components which are; Physical/Chemical assessment, Biological/Toxicological assessment, and Land Use assessment.

DNR/USGS OBSERVATION WELL NETWORK, Laurel D. Reeves, Minn. Dept. of Natural Resources, Division of Waters, St. Paul, MN 55155-4032.

The observation well network has been developed to record background levels in areas of present or expected future ground water use. This data is used to assess ground water resources, interpret impacts of pumping and climate, plan for water conservation, evaluate local water complaints and otherwise provide for the management of the resource.

The network is composed of two sub-networks. One managed by the U. S. Geological Survey (USGS) and the other by the Minnesota Department of Natural Resources, Division of Waters (DNR). The USGS network currently includes approximately 150 wells. These wells are located throughout the state in many different aquifers and are the basis for the state-wide summaries of ground water levels published by the USGS. These wells are often part of USGS studies.

The observation well measurements for the DNR's portion of the network are taken primarily by the local Soil and Water Conservation Districts (SWCD). The DNR also measures some wells statewide. Currently 53 SWCDs are involved in monitoring approximately 500 wells statewide. This is up from 48 SWCDs reading 414 wells in 1987. Additions to the SWCD network are made by use of existing wells which meet observation well criteria, by assuming wells in the USGS network or by drilling new wells. Installation of an observation well may also be required as a condition for issuance of a water appropriation permit. Criteria for inclusion of existing wells include: 1) the well must meet all state and local well codes, 2) a geologic log and well construction data to identify the well's aquifer must be available, 3) the well must be a single aquifer well only, 4) the well must not be active (non-pumping), and 5) the well must pass a slug test. A few irrigation wells are included in the system; however, they are only read before and after the irrigation season.

The DNR has developed a measuring agreement with each SWCD. The agreement describes, by legal description, the wells to be measured, the measuring frequency and the amount to be paid. The SWCDs record the observation well level data on report forms supplied by the DNR. The readings are reported to the DNR on a quarterly basis. Twice yearly each SWCD submits an invoice to the DNR requesting payment for the readings. The funds for these payments come from the annual water use reporting fees of water appropriation permit holders, as directed by the State Legislature.

An annual ground water report which includes both USGS and DNR/SWCD measurements is produced by the DNR and is available in the spring of each year. These annual reports provide the previous water year's data.

Current plans call for expansion of the observation well network. Additional new wells are planned in several locations where water level trouble either has been experienced or is anticipated or where very little data exists. More observation wells are planned in the Twin City metropolitan area also. Both new wells and existing wells are to be added.

TUESDAY MORNING, APRIL 10

9:00 POSTER SESSION: Minnesota East Ballroom

Abulaban, A., R. Andricevic and E. Foufoula-Georgiou, St. Anthony Falls Hydraulic Laboratory, Univ. of MN, Minneapolis. *Coupling of chemistry and transport to predict solute behavior.*

Boody, G., Center for Rural Community Development and Public Policy, Minneapolis. *Creating special protection areas for groundwater and sustainable agriculture: a strategy for local and community action.*

Daniil, E. and J.S. Gulliver, St. Anthony Falls Hydraulic Laboratory, Univ. of MN, Minneapolis. *Wave-influenced gas transfer.*

Delin, G.N., U.S. Geological Survey, St. Paul. *Hydrologic considerations for delineating groundwater recharge areas for wells, Rochester, Minnesota.*

Dorland, D., Natural Resources Research Institute, Univ. of MN-Duluth, and J. Stepun, Western Lake Superior Sanit. Dist., Duluth. *Reduction of heavy metals in wastewater effluent.*

Ellis, C.R. and H.G. Stefan, St. Anthony Falls Hydraulic Laboratory, Univ. of MN, Minneapolis. *Hydraulic design of a winter lake aeration system.*

Gulliver, J. and J. Woods, St. Anthony Falls Hydraulic Laboratory, Univ. of MN, Minneapolis. *Hydraulic model study for the St. Cloud Hydroelectric project.*

Hansen, R. and D. Herzfeld, Environmental Quality Section, MN Dept. of Agriculture, St. Paul. *"Rinse and Win!" A pesticide container education project.*

Helmlinger, K. and E. Foufoula-Georgiou, St. Anthony Falls Hydraulic Laboratory, Univ. of MN, Minneapolis. *Digital terrain analysis and hydrologic implications.*

Hines, J.W., Environmental Quality Section, MN Dept. of Agriculture, St. Paul. *Monitoring for pesticides and nitrate in Minnesota waters.*

King, S.O. and P.L. Brezonik, Dept. of Civil & Mineral Engineering, Univ. of MN, Minneapolis. *Bioaccumulation and toxicity of metals in an artificially acidified seepage lake.*

Kozloff, K. and S.J. Taff, Dept. of Agricultural Economics, Univ. of MN, St. Paul. *Micro-targeting cropland retirement for water quality improvement: measuring the benefits of increased information.*

Kumar, P. and E. Foufoula-Georgiou, St. Anthony Falls Hydraulic Laboratory, Univ. of MN. *Monitoring and short-term forecasting of severe storms.*

Mach, C.E., S.O. King and P.L. Brezonik, Dept. of Civil & Mineral Engrg., Univ. of MN. *Effects of acidification on trace metals in Little Rock Lake, WI.*

Mackedanz, R., Agronomy Services Div., MN Dept. of Agriculture. *Agriculture chemical incident response.*

Mattke, T.W. and J.S. Gulliver, St. Anthony Falls Hydraulic Laboratory, Univ. of MN, Minneapolis. *Causes of Minnesota ice jams.*

Megard, R.O., Dept. of Ecology, Evolution & Behavior, Univ. of MN, Minneapolis. *Studies of plankton and fish with microcomputer-based sonar.*

Morrison, D. and R. Andricevic, St. Anthony Falls Hydraulic Laboratory, Univ. of MN. *The effects of heterogeneity upon transport in porous media.*

Tuesday morning (continued)

Myers, G. and S. Magdalene, Groundwater and Solid Waste Div., MN Pollution Control Agency. *Minnesota Pollution Control Agency statewide groundwater quality monitoring program.*

Olson, W.W., B.L. Yust and E.W. Morris, Dept. of Design, Housing and Apparel, Univ. of MN, St. Paul. *Residential point-of-use water treatment.*

Pfannkuch, H.-O., Dept. of Geology & Geophysics, Univ. of MN, Minneapolis. *Application of knowledge-based expert systems to models of hydrogeologic vulnerability and wellhead protection.*

Peckham, J., MN Dept. of Agriculture, St. Paul. *Bulk agrichemical permitting regulations.*

Peckham, J., MN Dept. of Agriculture, St. Paul. *Chemigation.*

Thene, J.R. and J.S. Gulliver, St. Anthony Falls Hydraulic Laboratory, Univ. of MN, Minneapolis. *Gas transfer at hydraulic structures.*

COUPLING OF CHEMISTRY AND TRANSPORT TO PREDICT SOLUTE BEHAVIOR.
Abdelkarim Abulaban, Roko Andricevic, and Efi Foufoula-Georgiou, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, MN. 55455

The ability to simulate (predict) the movement and fate of pollutants in groundwater is a major technological challenge. Almost every type of chemical species reacts with the soil structure and undergoes some transformation. There is a clear need for better understanding of the transport and fate of pollutants which is essential for management of water quality of our groundwater resources. To deal with such problems usually a coupled model of transport and chemical processes is necessary. In this paper, we will present our recent results on developing a coupled model which simulates the movement and fate of adsorbing solutes in heterogeneous porous media. The equilibrium sorption is modeled with the time-splitting technique and kinetic non-equilibrium is described as a birth and death process, a subset of Markov processes, which may have a spatially variable reaction rate. The use of a birth and death process is especially attractive since it can be easily extended to the case of multicomponent chemical reactions and exhibits moderate computational requirements. The developed methods are expected to provide useful simulation tools for testing different management strategies as well as for designing monitoring networks to detect pollutant movement. They can also be used for the study of in-situ bioremediation problems which in case of organic pollutants offer the only effective means of aquifer restoration.

CREATING SPECIAL PROTECTION AREAS FOR GROUNDWATER AND SUSTAINABLE AGRICULTURE; A STRATEGY FOR LOCAL COMMUNITY ACTION.
George Boody, The Minnesota Project, Center for Rural Community Development and Public Policy, 2222 Elm Street S.E., Minneapolis, MN 55414.

The Midwest Consortium on Groundwater and Farm Chemicals, a group of non-profit organizations from six states, staffed by the Minnesota Project, has researched model policy tools and developed a strategy for creating special protection areas for groundwater and sustainable agriculture at the local level. The goal is to prevent future groundwater pollution in areas of relatively high productivity that are also sensitive to groundwater pollution from normal use of farm chemicals. Elements of the strategy are: (1) understanding sustainable agriculture, (2) involving the community in decision making, and (3) adapting model policy tools including existing and potential educational, incentive, and regulatory programs.

WAVE INFLUENCED GAS TRANSFER.
Ekaterini Daniil and John S. Gulliver, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, MN. 55455

Air-water gas transfer is a source or sink of chemicals that impact environmental pollution, water quality, and climatic changes. Traditionally, the transfer of oxygen (reaeration) has been of most interest, but more recently attention has also focused upon gas transfer as a source or sink of toxic pollutants. Water bodies, especially the oceans, also represent a sink for greenhouse gases that have an impact on global climatic variations.

Recent studies of air-water gas transfer and comparisons between large and small wind wave flume data have indicated the potential importance of waves in the gas transfer process. Experimental evidence is presented showing that non-breaking deep-water gravity waves significantly influence air-water gas transfer. Comparison against data reported in the literature indicates that approximately fifty percent of the observed gas transfer in wind wave flume experiments can be attributed to non-breaking waves. The presence of bubbles, or bubble entraining breaking waves, enhance the gas transfer coefficient considerably. Visual correlation between breaking intensity and the transfer coefficient was very good, although the relation has not been quantified. This work is designed to help us separate the influence of wind and waves on gas transfer, so that predictive equations developed from data taken in wind-wave flumes may be applied to water bodies with large, more developed wave fields, such as reservoirs, lakes, and oceans.

HYDROLOGIC CONSIDERATIONS FOR DELINEATING GROUNDWATER RECHARGE AREAS FOR WELLS, ROCHESTER, MINNESOTA. Geoffrey N. Delin, Hydrologist, U.S. Geological Survey, 702 U.S. Post Office Building, St. Paul, MN 55101.

Accurate delineation of recharge (wellhead-protection) areas for wells is an important requisite to protecting groundwater quality. Zones of transport and zones of contribution are two types of recharge areas that can be delineated. Analytical-calculation, numerical-modeling, and hydrogeologic-mapping methods were used to delineate recharge areas for two high-capacity municipal wells completed in the partially karstic St. Peter-Prairie du Chien-Jordan aquifer in the city of Rochester, southeastern Minnesota. Well 11 is less than 1,000 feet from the South Fork Zumbro River in an area where the aquifer is unconfined; well 26 is more than 2,000 feet from Cascade Creek in an area where the Decorah-Platteville-Glenwood confining unit is present.

Zones of transport are delineated by analytical calculations and by numerical modeling that account for hydrologic factors in different levels of detail and accuracy. Groundwater travel times from points along the top of the aquifer to a pumped well are identified by isochrones (contours of equal travel time). A zone of transport, therefore, is defined by the area bounded by an isochrone. Analytical calculations used to calculate zones of transport include fixed-radius (Theis drawdown, Theis time-of-travel, and volumetric equation). and variable shapes (zone of contribution truncated by a time-of-travel distance and modified ellipse, calculated with an analytical solution). Numerical modeling was done with the U.S. Geological Survey three-dimensional ground-water-flow model MODFLOW and particle-tracking code MODPATH. The zone-of-transport areas for each of the two wells did not differ substantially using the different analytical calculations. The zone-of-transport areas computed by numerical modeling were generally larger than areas computed by analytical calculations. The zone-of-transport areas computed by the Theis-drawdown method compared least favorably with results from other methods.

Hydrogeologic mapping and numerical modeling were used to delineate zones of contribution to wells, defined as all parts of a groundwater-flow system that could supply water to a well. The zones of contribution delineated by numerical modeling have similar orientation (parallel to regional flow directions) but significantly different areas than the zones of contribution delineated by hydrogeologic mapping. Differences in computed areas of recharge are attributed to the capability of the numerical model to more accurately represent (1) the three-dimensional flow system, (2) hydrologic boundaries like streams (3) variable recharge, and (4) the influence of nearby pumping wells.

REDUCTION OF HEAVY METALS IN WASTEWATER EFFLUENT. Dianne Dorland, Natural Resources Research Institute, University of Minnesota, Duluth, MN and Joseph Stepun, Western Lake Superior Sanitary District, Duluth, MN.

The solid waste processing facility for Duluth, MN was completed in 1981 and processes over 300 tons of solid waste/day from residential, commercial, and industrial sources. After removal of non-combustible materials (metal and glass), the system produces an average of 150 tons of refuse derived fuel (RDF) each operating day. The facility is coupled with a wastewater treatment plant having an average daily flow of 43 million gallons. The sewage sludge is burned in a fluidized-bed incinerator fueled by the RDF, reducing the required landfill volume.

The sewage sludge incineration has resulted in an increase in heavy metal concentrations in the wastewater effluent. Increased mercury concentrations now exceed new NPDES discharge limits and independent studies in the St. Louis Bay indicate significant concentrations of mercury in the water in the area of the wastewater effluent.

To address this problem, a multi-step project was undertaken: (1) evaluation of the process flows and compositions identified the best removal points; (2) the metal forms present were characterized; (3) laboratory tests using plant process streams determined the best removal methods; and (4) equipment was purchased and installed in the plant to remove heavy metals.

This paper reports the process evaluation, plant changes, and current wastewater effluent operating levels.

HYDRAULIC DESIGN OF A WINTER LAKE AERATION SYSTEM. C.R. Ellis and H.G. Stefan, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, MN. 55455.

Shallow, eutrophic lakes in the upper Midwest of the United States are subject to fish mortality due to oxygen depletion under ice (winterkill). Current practices employed to prevent this phenomenon typically create an area of open water which poses a hazard to winter lake users. An aeration system has been designed and hydraulically modeled that (a) will maintain consumption and (b) will not destroy or weaken the ice cover. By maintaining a stable density stratification, this new aeration technique prevents warm water from the bottom from moving to the surface where ice melting would occur and separates oxygenated water from the sediment where most of the winter oxygen demand is found.

THE HYDRAULIC MODEL STUDY FOR THE ST. CLOUD HYDROELECTRIC PROJECT. John S. Gulliver and Judson Woods, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, MN. 55455

After selecting two 4.3 M turbine-generator units for the St. Cloud Hydroelectric Project, a model study was required to evaluate and improve the hydraulic characteristics of the plant's intake and approach flow regions. The model layout and 1:24 scale size were established to ensure approach flow conditions in the model would adequately simulate the prototype. Significant benefits and conclusions derived from the model study: 1) intake vortices were observed and then eliminated in the model through the use of an anti-vortex device - a submerged grid - which was subsequently incorporated into the prototype, 2) a large separation zone near one bank and surface waves, due to shallow water upstream, were virtually eliminated by reconfiguring the approach flow region in the model, 3) head losses were measured in the model, scaled up to the prototype, and used in riprap design.

"RINSE AND WIN!" A PESTICIDE CONTAINER EDUCATION PROJECT FOR MINNESOTA. Rick Hansen and Dean Herzfeld, Environmental Quality Section, State of Minnesota, Department of Agriculture,. St. Paul, MN 55107.

"Rinse and Win!", an education and demonstration project promoting the proper rinsing and disposal of empty pesticide containers was developed and conducted in 1989. Through a cooperative effort of farm, industry, environmental, agency and university groups, the project emphasized safety, economics and the environment as reasons for properly rinsing pesticide containers. Proper rinsing was promoted as an agricultural management practice to minimize surface and groundwater contamination. The project provided information to farmers and other pesticide users and demonstrated proper rinsing techniques.

DIGITAL TERRAIN ANALYSIS AND HYDROLOGIC IMPLICATIONS.
Keith Helmlinger and Efi Foufoula-Georgiou, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, MN. 55455.

Several hydrologic features, such as watershed boundaries and drainage networks, can be automatically extracted from digital elevation models after a "contributing support area" is selected as the threshold that defines the smallest scale of the river network. The physical interpretation of the support area is very important for rainfall-runoff modeling since it points our the scales at which hillslope and channel flow processes take place. However, selection of different size support areas results in different river networks with different drainage densities and other properties. Previous studies have suggested to select the basic scale as the scale at which a break in the scaling of the river network is found, the interpretation being that at that scale the nature of the sediment transport process changes from the hillslope regime to the channel regime. In this study, we have investigated an alternative approach in which the basic scale is sought by looking directly at the scaling of the "roughness" of the two-dimensional landform surface rather than the scaling of the extracted river network.

MONITORING FOR PESTICIDES AND NITRATE-NITROGEN IN MINNESOTA WATERS. John W. Hines, Minnesota Department of Agriculture, Environmental Quality Section, 90 W. Plato Blvd., St. Paul, MN 55107.

The Minnesota Department of Agriculture has been monitoring for pesticides in groundwater since late fall 1985. Currently there are over 90 wells included in the network, 30 of which are monitored on a quarterly basis for time-trend analysis. This poster paper provides information on how the monitoring program at MDA is designed, and what the crucial considerations are. The paper also presents information available from the previous years of monitoring for both pesticides and nitrate-nitrogen.

BIOACCUMULATION AND TOXICITY OF METALS IN AN ARTIFICIALLY ACIDIFIED SEEPAGE LAKE. Scott King and Patrick L. Brezonik. Department of Civil & Mineral Engineering, University of Minnesota, Minneapolis, MN 55455.

Changes in lakewater pH are known to affect the bioavailability and toxicity of many metals to aquatic organisms. The division of Little Rock Lake, Wisconsin into a reference basin and an acidified basin provides a unique opportunity to study the effects of acidification on the bioaccumulation of metals. Body burdens of Al and Cd in periphyton (artificial substrate), zooplankton, amphipods, Chaoborus, whole fish (yellow perch and largemouth bass), and fish tissue (muscle, skin, gills, and stomachs) for the reference basin (pH of 6.1) and the acidified basins (pHs of 5.1 and 4.7) will be presented. The effects of artificial acidification on the bioaccumulation metals in the aquatic organisms of Little Rock Lake will be discussed.

MICRO-TARGETING CROPLAND RETIREMENT FOR WATER QUALITY IMPROVEMENT: MEASURING THE BENEFITS OF INCREASED INFORMATION. Keith Kozloff and Steven J. Taff, Department of Agricultural Economics, University of Minnesota, St. Paul, MN. 55108.

The relative cost effectiveness of micro-targeting cropland retirement programs for reducing non-point source pollution is examined using a computer model to simulate the effects of various program options in a study watershed with respect to budget outlays for annual rental payments, reduction in downstream sediment and nutrients, and reduction in on-site erosion. Options that incorporated information about heterogeneous economic and physical characteristics across land parcels were more cost effective than those that did not. The marginal cost effectiveness of all schemes decreased as the proportion of land retired increased with the watershed.

MONITORING AND SHORT-TERM FORECASTING OF SEVERE STORMS. Praveen Kumar and Efi Foufoula-Georgiou, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, MN. 55455

Short-term precipitation forecasting (10 min up to a few hours and spatial resolution of a few km) can be accomplished by monitoring the motion, shape, size, and intensity of clouds and precipitation fields and extrapolate their trends in space and time. The basic data for extrapolative forecasting methodologies are radar data (reflectivity factor at a single height level or the vertically integrated liquid (VIL) which in most cases results in more accurate forecasts) and/or satellite infrared and visible imagery data. Past efforts have been directed towards advection or crosscorrelation methods which basically translate the whole precipitation field. Our research is directed towards methods that can account for evolution of smaller scale precipitation areas within the rainfall field of interest. Under this method, feature areas are extracted by thresholding the data with selected intensity levels forming thus a series of areas enclosed within contour boundaries. These areas are then monitored and forecasted. In this paper techniques of extrapolative short-term forecasting of extreme precipitation fields will be demonstrated using data from an unusually severe storm monitored by the National Severe Storms Laboratory (NSSL) radar in Central Oklahoma.

EFFECTS OF ACIDIFICATION ON TRACE METAL CHEMISTRY IN LITTLE ROCK LAKE, WI. Carl E. Mach, Scott O. King, and P.L. Brezonik. Department of Civil & Mineral Engineering, University of Minnesota, Minneapolis, MN 55455.

Apart from lowering the pH of surface waters, one of the most harmful effects of acid precipitation is to mobilize potentially toxic metals (e.g. Al, Fe, Mn, Cd, Zn) in the environment. Lake-chemistry surveys indicate that a large number of lakes in northeastern Minnesota are susceptible to acidic precipitation. These low-alkalinity lakes can be divided into 4 categories depending on their hydrologic characteristics: drainage lakes (75%), seepage lakes (16%), closed lakes (8%), and reservoir lakes (2%). Seepage lakes are highly susceptible to acidic precipitation because most water input is from rain or snow directly to the lake surface.
The most thorough study to date of seepage-lake acidification is presently being conducted at Little Rock Lake, a low-alkalinity seepage lake in northcentral Wisconsin. The two basins of the lake were separated by a polyvinyl barrier and stepwise acidification (2 years each at pH 5.6, 5.1 and 4.6) of the north basin with sulfuric acid began in 1985. The south basin (pH 6.1) was left as a reference; no acid was added. Of the 7 metals (Al, Fe, Mn, Cd, Cu, Pb, Zn) routinely measured at Little Rock Lake, only "dissolved" Mn (0.4 u pore-size filter) increased when the north basin was acidified from pH 6.1 to 5.6. Further acidification of the north basin to pH 5.1 resulted in an additional increase in "dissolved" Mn and concurrent increases in "dissolved" Al, Fe, Cd, and Zn. This poster will summarize trace metal data from the first 4 years of the Little Rock Lake acidification experiment and discuss mechanisms regulating metal-ion concentrations in the lake.

AGRICULTURAL CHEMICAL INCIDENT RESPONSE. Roger Mackedanz, Agronomy Services Division, State of Minnesota Department of Agriculture, 90 W. Plato Boulevard, St. Paul, MN 55107.

The Minnesota Department of Agriculture is the lead state agency in regard to agricultural chemical incidents. An incident is defined as any event that releases or threatens to release an agricultural chemical accidentally or otherwise into the environment, and may cause unreasonable adverse effects on the environment. In the event of an incident, the party responsible for the release must report that incident to the Department of Agriculture [(612)-649-

5451 or 1-800-422-0798] and take all action appropriate and necessary for the cleanup of that release. As of July 1990, a responsible party may seek reimbursement for a portion of the costs incurred during the cleanup, providing that they reported the release and cooperated in cleaning-up the incident site. The poster presentation will summarize the Department of Agriculture's incident response program to date, along with outlining the obligations of a party responsible for an agricultural chemical incident.

CAUSES OF MINNESOTA ICE JAMS. Ted W. Mattke and John S. Gulliver, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, MN. 55455.

This poster describes conditions necessary for the formation of the two common types of ice jams - frazil ice jams and breakup ice jams. A given velocity, combined with ice roughness, channel width and length of straight ice covered channel are required for breakup ice jams. Turbulent open water at freezing and air temperatures well below freezing are required for frazil ice jams. Several case studies were investigated for each type and the causes were documented. Pictures and diagrams of sample jams, and resulting jams are shown.

STUDIES OF PLANKTON AND FISH WITH MICROCOMPUTER-BASED SONAR.
Robert O. Megard, Professor, Department of Ecology, Evolution, and Behavior, University of Minnesota, Minneapolis, MN 55455.

A high-frequency sonar unit and a Loran "C" navigation receiver have been interfaced with a microcomputer to describe the abundance and spatial distribution of zooplankton and fish. The system is portable, for use on small boats, and uses an acoustic frequency (200 kHz) that detects both fish and zooplankton as small as 0.5 mm in length. An A/D converter in the computer digitizes the strength of all echoes, and color echograms are displayed instantaneously on the computer monitor. The data files, usually obtained along transects, are large (typically 1-5 megabytes) so they are recorded first on the computer's hard disk and them moved to 200-megabyte optical disks for subsequent display and analyses. The distribution of plankton and fish in some Minnesota lakes will be described with color echograms and with depth profiles of echo strength.

THE EFFECTS OF HETEROGENEITY UPON TRANSPORT IN POROUS MEDIA.
Deane Morrison and Roko Andricevic, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, MN. 55455.

It is well known that subsurface porous material exhibit a large degree of natural variability. Geologic formations are often characterized by highly variable three dimensional structures consisting of layers, lenses, and perhaps fractures in various material types. As a consequence to these material fluctuations is a similar variability in the hydrogeological parameters (conductivity and porosity) used for the description of both flow and transport in porous media. Most of the field data indicated that hydraulic conductivity follows a lognormal distribution. In this paper the locally variable hydraulic conductivity is represented as a realization of stationary spatially correlated random field. Random field is characterized by its first two statistical moments, namely the mean, variance about the mean, and a correlation structure with an associated correlation length scale. Numerical experiments are performed to investigate the effects of different random field characteristics upon the conservative plume behavior. Groundwater transport was analyzed based on the spatial moments, e.g. average center of mass displacement, variance (spread) of the plume, dispersion effect and break-through curves. The results obtained from numerical simulations indicate that relatively small changes in variability of hydraulic conductivity may singificantly alter the plume behavior in terms of mean displacement, spreading and arrival time. The results apparently emphasize the importance of properly assessing hydraulic conductivity variations in the field scale contaminant transport problems.

MINNESOTA POLLUTION CONTROL AGENCY STATEWIDE GROUND WATER QUALITY MONITORING PROGRAM. Georgianna Myers and Sue Magdalene, Ground Water Solid Waste Division, Minnesota Pollution Control Agency, 520 Lafayette Rd., St. Paul, MN 55155.

In 1979, the Minnesota Pollution Control Agency established the Ambient Ground Water Monitoring Program to define baseline water quality conditions and evaluate statewide water quality trends. Since that time, the program goals have expanded to include assessing the extent of ground water contamination resulting from land use activities. To date, approximately 1,100 ground water samples representing 450 monitoring sites have been collected on a rotating schedule. These samples have been analyzed for a suite of inorganic, organic, bacteriological and physical parameters. Exceedances of drinking water standards were detected in the following parameters, in order of decreasing frequency: iron, manganese, sulfate, nitrate and chloride. Elevated nitrate concentrations were most commonly encountered in the surficial sands aquifers of southwestern Minnesota and the Mississippi River Basin, and the carbonate aquifers in the karst region of southeastern Minnesota. Volatile organic compounds were detected in 11% of the 375 samples analyzed. This program is currently being redesigned to provide more complete and useful ground water quality data to state, local, private and other groundwater resource managers.

RESIDENTIAL POINT-OF-USE WATER TREATMENT. Wanda W. Olson, Becky Love Yust, and Earl W. Morris, Department of Design, Housing, and Apparel, University of Minnesota, St. Paul, MN 55108.

Few studies focus on the issue of safe drinking water in rural communities from the perspective of the household members. The rural household on a private water supply is particularly vulnerable because it is outside the jurisdiction of safeguards such as the Federal Safe Drinking Water Act. This study was done to assess the household's drinking water quality, awareness of the quality of their water, the use of technology to manage household water quality, satisfaction/dissatisfaction with water quality and evaluation of reverse osmosis treatment devices to mitigate water problems. Heads of households in two agricultural counties were surveyed to determine household water management and practices. The sample of 50 households was solicited through advertisements and contacts through retailers of reverse osmosis treatment devices. Additional households adjacent to 14 of the original sample were surveyed to compare drinking water quality and attitudes and practices of the

household members. The survey ascertained respondent knowledge, attitudes about water quality and their use of water treatment devices. Water quality was determined by water sample analyses of iron, chlorides, sulfates, and nitrates. Additional tests were performed to detect coliform and other bacteria.

Rural residents in this study had strong opinions concerning their water quality. Residents with reverse osmosis devices were more likely to consider the groundwater quality situation as serious and that untreated water was unsafe for drinking than residents without reverse osmosis devices. Overall, subjects were satisfied with their drinking water situation, even though in households without reverse osmosis devices there were cases where drinking water standards were exceeded. Most frequently, these occurred in households where the water was supplied from a private source. While municipal water supplys are regulated to meet EPA primary drinking water standards, households on private water systems need to initiate periodic independent testing to assure safe drinking water. Where incoming water exceeded the MCL, the percentage reduction of contaminants after passing through a reverse osmosis device varied from 14% to 100% but all treated drinking water was below the MCL's for contaminants.

Although some individuals were willing to spend a significant amount of money for point-of-use water treatment, objective information on water quality and water treatment devices was limited at the consumer level. Testing to determine contaminants which exceed EPA standards should be done prior to purchase of water treatment devices. Documentation of manufacturer's claims need to be presented in a consistent and clear format for use by consumers when they are making purchase decisions.

This study was funded in part by the Minnesota Extension Service and the Brown-Nicollet Board of Health. The authors wish to acknowledge the assistance of the following individuals: Rosemary Heins, Nicollet County Extension Agent; Gail Waldner, Brown County Extension Agent; Bonnie Holz, Brown-Nicollet Board of Health Director; and Julie Soehren, Project Research Assistant.

APPLICATION OF KNOWLEDGE BASED EXPERT SYSTEMS TO MODELS OF HYDROGEOLOGIC VULNERABILITY AND WELLHEAD PROTECTION SCHEMES.

Hans-Olaf Pfannkuch, Professor, Department of Geology & Geophysics, University of Minnesota, Minneapolis, MN. 55455.

Recent legislation in Minnesota (Groundwater Protection Act, Chapter 326 of Minnesota Session Laws, 1989) has focussed on groundwater protection strategies. To fulfill its mandate, especially in the areas of wellhead protection and determination of aquifer vulnerabilities with reference to land-use, large numbers of professionals are required. It will be difficult to fill all open hydrologist positions with experienced professionals. Expert systems are computerized knowledge based reasoning systems that capture and replicate the problem solving capabilities of human experts and aid in the decision-making process. Expert systems have the following advantages: novices and non-specialists are aided and guided in the decision making process, expert time is freed up to solve truly complex problems, the highly structured organization of the knowledge base and production rules results in a uniform application of the procedures, and application of the expert system by the novice serves as a tutoring guide to help develop the novice more efficiently to an expert at the same time it solves the problem.

Expert systems and computerized decision support systems using hydrogeologic knowledge bases and production rules are most suitable for solving problems in groundwater protection such as delineation of wellhead protection zones, definition of aquifer sensitivity to various land-use practices, and the hydrogeologic evaluation and rating of groundwater vulnerability. The common denominator of these procedures is to assess the risk that is associated with certain land use practices, the probability that stresses or contaminants propagate through the different hydrogeologic compartments or path modules and the likelihood that they enter environmentally sensitive or critical use areas. This risk assessment procedure can best be represented by passage through a forward or backward chaining decision tree procedure, where at each node or decision point the expert system prompts the decision maker to assign a range of values to the state parameters and thereby arrive at a rating score. The numerical value of the score will then aid in taking the next step. Vulnerability assessments are pure classification and ranking systems, whereas wellhead protection schemes also involve the active determination and delineation of protection zones based on hydrologic modeling of travel times and zones of contribution to the pumping wells. This can be accommodated by integrating these numerical models into the decision branching system contained in the expert system shell. This presentation discusses the encoding of knowledge bases and rules into a system of decision trees and rating grids suitable for micro-computer application. Such an interactive computer code will lead the user through the problem solving process step by step in a very structured and uniform manner. The objectives of this presentation is to discuss the general structure of expert systems suitable for hydrogeologic application and through its format as a poster session initiate a dialogue to assess the needs of potential users.

BULK AGRICHEMICAL PERMITTING REGULATIONS. John Peckham, State of Minnesota Department of Agriculture, 90 W. Plato Boulevard, St. Paul, MN 55107.

The MDA has had an active program of granting approval for safeguards at storage sites since 1976. MDA's responsibilities have been expanded recently with the adoption of MDA's Bulk Pesticide Storage Rule and the addition of permitting responsibilities in Minnesota's Comprehensive Ground Water Protection Act. The existing and new regulations will insure protection of Minnesota's surface water and ground water through the construction of safeguards which will prevent leaching of pesticides into ground water and surface run-off from agrichemical storage facilities.

These regulations could potentially affect 800+ agrichemical sites in Minnesota.

The bulk storage topic will be conveyed on an individual poster display.

CHEMIGATION. John Peckham, State of Minnesota Department of Agriculture, 90 W. Plato Boulevard, St. Paul, MN 55107.

The MDA adopted Minnesota's Chemigation Safety Regulation on January 1, 1989. This regulation sets forth a permitting program and mandates that specific types of anti-pollution equipment be used when pesticides, including fungicides, insecticides, herbicides, etc. are applied through irrigation systems.

As a result of Minnesota's Comprehensive Ground Water Protection Act, regulations regarding the application of fertilizer through irrigation are now being developed.

These two regulations may potentially affect 3500+ growers in Minnesota.

The chemigation topic will be conveyed on an individual poster display.

GAS TRANSFER AT HYDRAULIC STRUCTURES. John R. Thene and John S. Gulliver, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, MN. 55455.

Gas transfer at hydraulic structures is an important source or sink of dissolved gas in a river system, even though the water is in contact with the structure for a short period of time. The primary reason is that bubbles are entrained into the flow, greatly enhancing the surface area available for gas transfer. This poster will discuss the applications of hydraulic structure gas transfer measurements and two measurement techniques for gas transfer. The mid-winter technique measures dissolved oxygen (D.O.) concentration under the ice cover when D.O. deficits are high and D.O. stratification is insignificant. A hydrocarbon technique uses an injected gas tracer such as propane. Samples of the injected propane are taken upstream and downstream of the structure, and evaluated for propanc concentration on a gas chronotagraph.

TUESDAY AFTERNOON

SECTION 1. Fisheries of Lake Superior and the Lake Superior Initiative: Senate Suite; Organizers: D. McNaught, Sea Grant College Program, Univ. of MN and R. Hassinger, MN Dept. of Nat. Resources, St. Paul

1:20 Opening remarks: D. McNaught

1:30 R. Hassinger, Dept. of Natural Resources, St. Paul. *Yield to anglers from Lake Superior.*

1:55 D.R. Schreiner and S.D. Morse, Dept. of Nat. Resources, Duluth. *Fisheries management in the Minnesota waters of Lake Superior.*

2:20 S.D. Morse and D.R. Schreiner, Dept. of Nat. Resources, Duluth. *Commercial fishing in the Minnesota waters of Lake Superior.*

2:45 G. Spangler, Dept. of Fisheries & Wildlife, Univ. of MN, St. Paul. *Policy options for Native American fisheries.*

3:10 Refreshment Break

3:30 J.L. Gunderson, Sea Grant Extension Program, Univ. of MN, Duluth. *Lake Superior anglers: effects on management decisions.*

3:55 R.M. Carlson, University of MN, Duluth. *The Lake Superior Initiative.*

4:20 S.J. Eisenreich, Dept. of Civil & Mineral Engineering, Univ. of MN. *Physical, chemical, and ecological issues on Lake Superior.*

4:45 Discussion and questions

THE MINNESOTA SPORT FISHERY IN LAKE SUPERIOR. Richard L. Hassinger[1]; Stephen D. Morse[2] and Donald R. Schreiner[2], MN-DNR, 500 Lafayette Road, St. Paul, MN 55155[1]; MN-DNR, 5351 North Shore Drive, Duluth, MN 55804[2]

Minnesota fishery resources offer a broad diversity of angling opportunities. Lake Superior and the anadromous portion of its tributaries are significant components of this diversity. Lake Superior and its tributaries support significant boat and shore sport fisheries for a variety of salmonids including lake trout, steelhead (rainbow), Atlantic salmon, coho salmon, chinook salmon and brown trout. In addition, the North Shore fishery is not a single-season fishery; opportunity exists for angling year-round. These varied opportunities were not available 25 years ago.

During the first half of this century lake trout were the mainstay of the sport and commercial fisheries on Lake Superior. The population provided an annual commercial harvest of 354,000 pounds and supported an insignificant harvest by the sport fishery. By the late 1940s the commercial harvest had begun to decline, presumably due to overfishing. The mean annual commercial take from 1941 to 1950 was 249,000 pounds. While early sport harvest estimates are not available, North Shore residents recall an active charter fishery between Grand Portage and Duluth. Many of the charter operators were commercial trout netters who set their nets aside during the summer months to take sport anglers out for lake trout. Most non-charter fishing took place from shore and in the streams targeted at other game fish such as native coaster brook trout and naturalized steelhead and brown trout.

By the mid- to late-1950s, an additional mortality factor became established in Lake Superior--the sea lamprey. The lake trout population, already exposed to heavy exploitation, collapsed in response to the additional mortality imposed by the sea lamprey. By 1961 the commercial harvest had been reduced to 1,000 pounds. The effect of lamprey is not well-documented for other species although marking data for steelhead suggest it is reasonable to presume other sport fish species were affected. With this dramatic change in the fish community, the charter and lake fishery become non-existent.

By the mid-1960s effective sea lamprey control had been achieved, and Minnesota embarked on an ambitious salmonid stocking program in Lake Superior and its tributaries that included the introduction or re-introduction of lake trout, rainbow trout and Pacific salmon. Atlantic salmon have recently been added to the list. A creel survey was initiated on Lake Superior in 1969 to supplement lake trout assessment data and monitor the success and contribution of plants of other salmonids. This first survey covered one access point and received 87 lake trout, 93 coho salmon, and 52 rainbow trout. The spring anadromous fishery was first monitored from 1961 to 1967. The spring fishery was not surveyed again until 1981 but has since been monitored annually.

Creel surveys on Lake Superior and its tributaries have expanded in scope and technique as the sport fishery and survey methodology have developed. The Lake Superior fishery has been monitored annually since 1969, and a growing fall anadromous fishery generated by plants of chinook salmon prompted fall surveys in 1986, 1987, and 1989. In 1990 the first winter survey was conducted and targeted both anadromous and lake species.

The expanding fish population in Lake Superior has stimulated a major increase in angling pressure. The Duluth-Superior harbor presently supports the largest charter fleet on Lake Superior and provides the community with a significant economic asset. Individual sport anglers have also increased, and comprise a major component of the north shore tourist economy. As the sport fishery becomes more of an economic factor in the states economy, the sustained health of the fish community will take on an even greater significance in the future.

FISHERIES MANAGEMENT IN THE MINNESOTA WATERS OF LAKE SUPERIOR.

Donald R. Schreiner and Stephen D. Morse, MN-DNR, Lake Superior Area, 5351 North Shore Drive, Duluth, MN 55804.

The MN-DNR Fisheries Section is responsible for fisheries management and assessment in the Minnesota waters of Lake Superior. Management objectives for Lake Superior are coordinated through the Great Lakes Fishery Commission which is comprised of all agencies that surround the lake, two indian tribes and the U.S. Fish and Wildlife Service. Over the last 100 years, the Lake Superior fish community has undergone dramatic changes due to excessive harvest and the establishment of exotic species. The major goal for the Lake Superior fishery is the rehabilitation of self-sustaining lake trout (*Salvelinus namaycush*) stocks to historical levels of abundance.

Lake trout stocks, already exposed to heavy exploitation, were devastated by the invading sea lamprey in the late 1940s and early 1950s. Lake trout rehabilitation efforts include: controlling sea lamprey; stocking yearling lake trout; restricting the commercial harvest to only special assessment nettings; identification, protection and monitoring of spawning reefs and the imposition of bag limits and seasons on the sport fishery. stocked fish still comprise the bulk of Minnesota's lake trout, although natural reproduction has increased over the last 15 years, and is now approaching 20%. Lake trout is the primary species captured by anglers. The present lake trout population supports an expanding sport fishery with an average annual harvest of 18,400 fish over the last 5 years.

In the 1960s and early 1970s, exotic salmonid species were introduced into Lake Superior to establish a near-shore sport fishery, while reducing pressure on lake trout stocks. Coho salmon (*Oncorhynchus kisutch*) have become naturalized in Lake Superior over the last 25 years with natural reproduction occurring in many of the tributaries. Although there is presently no active management program in Minnesota for coho, they represent the second most abundant species in the sport fishery. Chinook salmon (*O. tshawytscha*) have been stocked in Minnesota waters since 1974 supporting a major stream fishery in the fall and a growing trolling fishery during the open water season. Presently 500,000 chinook are stocked each spring in the Lester, French, Baptism and Cascade Rivers. An interagency, lakewide study is in progress to assess the presence and extent of natural reproduction among chinook. The study will also document migration, straying and the relative contribution each agency's stocking program is making to the sport fishery.

Anadromous rainbow trout (*O. mykiss*) or steelhead have become naturalized in Lake Superior since their first introductions in 1895. Steelhead are found in all major tributaries along the Minnesota shoreline and support an important recreational fishery. Kamloops rainbow trout were introduced in the early 1970s to establish a put-grow-and-take anadromous rainbow fishery that would supplement the growing harvest of the naturalized steelhead fishery. Steelhead fry stocking and an experimental steelhead smelt program have also been implemented to help support the growing steelhead fishery.

Herring (*Coreqonus artedii*) and rainbow smelt (*Osmerus mordax*) support the present commercial fishery and provide the major forage base for large predators. Population levels have moved in opposite directions since smelt increased while herring decreased. Since the early 1980s, trends in abundance have reversed with herring on the increase and smelt declining. The population dynamics of these species continue to be monitored through commercial fishing records and assessment nettings as this information is essential to the management of both sport and commercial fisheries.

Public expectations are extremely high for the Lake Superior fish community based on the success experienced with lamprey control, lake trout rehabilitation, salmonid introductions and increasing herring populations. Although past management practices have contributed to this success, the fish community is still volatile and dynamic. Increased assessment, analysis, and information transfer using new and innovative techniques are essential to implementing future management strategies that will continue rehabilitation of this important fishery.

COMMERICAL FISHING IN THE MINNESOTA WATERS OF LAKE SUPERIOR.
Stephen D. Morse and Donald R. Schreiner, MN-DNR, Lake Superior ARea, 5351 North Shore Drive, Duluth, MN 55804.

Commercial fish production records for Minnesota waters of Lake Superior begin in 1885 when a catch of 10,000 lbs. of lake sturgeon, 628,000 lbs. of lake whitefish, 35,000 lbs. of lake herring and 1,376,000 lbs. of lake trout was recorded. The 1885 catch remains the highest Minnesota catch recorded for lake sturgeon, lake whitefish, and lake trout. Most species have undergone dramatic population changes in the last hundred years in response to commercial fishing, exotic introductions, and other factors.

Lake Sturgeon

Consistent record keeping starts in 1913 in Minnesota. In Ontario, lake sturgeon catch peaked in the late 1880s and declined rapidly around the turn of the century. Minnesota's catch may have followed the same pattern. Sturgeon are long-lived and slow growing, requiring about 20 years to reach sexual maturity. Both Minnesota and Wisconsin have planted lake sturgeon in St. Louis Bay in recent years. It is not anticipated that these lake sturgeon will provide a commercial fishery.

Lake Whitefish

Like lake sturgeon, lake whitefish have not been a large component of the commercial fishery in Minnesota since 1885. Unlike sturgeon, they have been a small but relatively consistent part of the fishery. Harvest has varied from less than 1000 lbs. to 15,000 lbs. Some whitefish fry were stocked in the period from the late 1930s through the 1950s. Today the area near the Ontario border provides the harvest, and whitefish are rare in the rest of Minnesota waters. Whitefish are harvested with large mesh gill nets set on the bottom. Presently, lake whitefish harvest is allowed only under lake trout and whitefish assessment permits.

Lake Trout

Lake trout production increased in the period from 1913 through 1920 and then remained relatively consistent for the next twenty years, averaging about 350,000 lbs. By the late 1940s harvest began to decline, presumably due to overfishing. By the mid to late 1950s sea lamprey had become established in Lake Superior. The already heavily exploited population collapsed in response to this additional mortality factor. By 1961 the harvest had been reduced to 1000 lbs. In 1962 Minnesota imposed strict limitations on both the sport and commercial harvest, limiting the take to the level required to effectively monitor the population. The Great Lakes Fishery Commission established effective lamprey control, and ambitious restocking began. Today, nearly thirty years later, both programs continue. The lake trout population has been partially rehabilitated. Natural reproduction is contributing significantly, but the bulk of the population in Minnesota waters is still composed of planted fish. Sport harvest has increased, but commercial harvest remains restricted to a permit assessment fishery. Lake trout are harvested with large mesh gill nets set on the bottom. Historically, they were also taken with hook lines suspended in open water and baited with small fish or pieces of fish.

Lake Herring

Lake herring production climbed steadily from 1913 through the 1920s. Production leveled off in the 1930s at about 6,300,000 lbs. annually, and then declined steadily, reaching a low of about 60,000 lbs. in 1985. Production since 1985 has increased slightly. SEveral factors may have been involved in the decline. Overfishing contributed initially. In the 1960s and 1970s, an increasing smelt population may also have played a part. The increase since 1985 has been coincidental with a decrease in the smelt population. Several measures have been instituted in an attempt to halt the decline including: limited entry to the commerical fishery and a cap on the amount of gear licensed, a closure of the fishing seasopn during the November spawning period, and a herring fry stocking program in the Duluth area from 1975-1986. Several recent strong year classes of lake herring have generated some optimism about herring recovery. Lake herring are harvested principally with small mesh gill nets suspended in open water.

Smelt

The smelt fishery resulted from the accidental introduction of smelt into the Great Lakes system. In Minnesota water, smelt first appeared in the commercial catch in 1958 with a harvest of about 290,000 lbs. Smelt harvest peaked at about 2,500,000 lbs. in 1977, and has declined since. The 1988 harvest was about 180,000 lbs. No effort has been made to increase the smelt population. Although smelt are used as forage by lake trout and other predators, they are themselves predators. AT some population levels they may have adverse impacts on the survival of juvenile lake trout and lake herring. Also, smelt are largely restricted to near shore waters. For this reason they have less potential for developing the large biomass of the historic lake herring population that served as a forage base for lake trout. Smelt are harvested with pond nets which are large traps that intercept smelt swimming near shore during the spawning run. There is also a limited trawl fishery near Duluth for smelt in the spring and fall months.

Chubs

Chubs include several related species that are impractical to distinguish for the purposes of commercial harvest reporting. Chubs are deep water relatives of the lake herring. Commercial fishers harvest them with gill nets set on the bottom. They are required to set in water 240 feet or deeper. Chubs have been a relatively minor component of the commercial 440,000 lbs. Unlike most of the other species discussed here, chubs have not undergone a dramatic population collapse or explosion. Harvest has fluctuated, with peaks in the mid 1920s, mid 1940s, and late 1960. The present low harvest (about 3000 lbs. in 1988) is probably related as much to market conditions and subsequent lack of fishing effort as to abundance, although an expanding siscowet population has probably reduced abundance in some areas.

The commercial fishery has changed greatly in the last hundred years. Today it is rather small with a total of about 410,000 lbs. of fish harvested in 1988, most of which was herring and smelt. Much of the harvest goes to local markets, especially the herring. Lake herring, sometimes called bluefin herring, has become a specialty of many small restaurants along the north shore of Lake Superior.

NATIVE AMERICAN FISHERIES ON LAKE SUPERIOR, IMPACTS AND POLICY ISSUES. George R. Spangler, Department of Fisheries & Wildlife, University of Minnesota, St. Paul, MN and Thomas Busiahn, Great Lakes Indian Fish and Wildlife Commission.

Native American fisheries are currently active in Lake Superior waters of both Canada and the United States. These fisheries increasingly provide subsistence and commercial benefits to several bands of Lake Superior Chippewa Indians while strengthening the stock assessment and surveillance networks available to fisheries managers. Agreements currently in force govern fishing on an intertribal basis in Wisconsin, Minnesota and Michigan, and on a state-tribal basis in Wisconsin and Minnesota. Cooperative efforts at stock assessment and management are in place in several jurisdictions serving Indian and non-Indian fisheries. Eleven of the nineteen U.S. lamprey spawning traps in Lake Superior tributaries during 1990 will be operated by Indian Fish and Wildlife management agencies. Landings, indices of year-class strength, mortality rates and other population assessment parameters are being estimated annually through efforts of state, provincial, tribal and federal management agencies for nearly a dozen key species in the Lake Superior fish community. The cooperation between Indian and non-Indian agencies around Lake Superior provides an excellent example of implementation of the provisions of the strategic Great Lakes Fishery Management Plan.

LAKE SUPERIOR ANGLERS: EFFECTS ON MANAGEMENT DECISIONS. Jeffrey L. Gunderson, University of Minnesota Sea Grant Extension, UMD, Duluth, MN 55812.

Review of nearly 10 years of activities of Lake Superior-related recreational fishing groups through personal observation, examination of their newsletters, and DNR reports has shown that anglers have had a major impact on Lake Superior and tributary fishery management activities. Management activities over the last decade were categorized as: 1. angler initiated, 2. management agency initiated, and 3. accidental management. While this categorization is subjective because of the cooperative nature of much of the management, there are some basic differences in the focus of the management activities initiated by anglers versus managers.

Anglers motivation to influence and direct management decisions on Lake Superior appear to stem from the "resource miracle" experienced on Lake Michigan following the introduction of Pacific salmon and what Richard Gale (Fisheries, 1987 vol 12:5) has termed a "revolution of rising expectations." The apparent decline in steelhead numbers returning to North Shore streams during the 1980s also played a significant role in angler participation in management. On the other hand, management agency motivation during this period was dominated by efforts to rehabilitate native stocks. This difference in motivation creates conflicts between anglers and managers that are rarely settled on the basis of scientific information.

Approximately 10 angler organizations currently exist in Minnesota that attempt to influence, in some way, Lake Superior fishery management policy. Each has a slightly different set of objectives for the fishery. Dealing with these groups, as a fishery manager, can be difficult because the groups conflict with each other over management directions and because they frequently bypass the management agency and attempt to "manage" through legislative action. Attempts by angler groups have, however, been made in the past to work together toward a common goal. Some attempts have been successful and others have not. Similarly, management agencies around Lake Superior meet regularly to formulate strategies for cooperative approaches to management. These efforts also result in both successful and some not so successful cooperative programs.

While management activities on Lake Superior seem chaotic at times because of user conflicts with the DNR, user conflicts with other user groups, and conflicts among management agencies around Lake Superior, it is the order of things for the time being. Overall, anglers work very closely with the DNR and support their management efforts with significant amounts of manpower, monetary donations, and legislative support. The DNR on the other hand supports angler initiated management when it is consistent with good management policy or will probably not have negative fishery impacts. While it is difficult to assess the success or failure of management initiatives of either anglers or managers, anglers have initiated many activities that are consistent with good fishery management and accomplished management objectives that would have been difficult for managers to otherwise accomplish.

The "fishery management miracle" of Lake Michigan still motivates angler involvement while fishery rehabilitation still tends to motivate management policy. But because of past and present socio-political-biological realities of fishery management in the Great Lakes, the motivations of anglers and managers may be coming together. The fact that many exotic species (and genetic strains) have been relatively recently introduced into the system will likely maintain the dynamic nature of Lake Superior for some time to come. The question is, will the changes we see in fishery stocks be viewed as opportunities for creating new miracles or for adapting to what we are dealt by the Great Lakes system?

THE LAKE SUPERIOR INITIATIVE. **Robert M. Carlson, Professor of Chemistry and Vice Chancellor for Academic Administration, University of Minnesota, Duluth, Duluth, Minnesota 55812**

The process for developing this research program was initiated with the Lake Superior Water Policy Conference in April 1988. This meeting, which was part of the Graduate School's 100th anniversary celebration, provided limnologists, oceanographers and individuals with the opportunity to present scientific, economic and public policy perspectives. These have been developed into the conceptual framework for the Lake Superior Initiative.

The submission of a report to the Legislative Commission on Minnesota Resources (LCMR) completes the first part of this study. It provides a research agenda for Lake Superior and proposes that Minnesota's research on Lake Superior be carried out within a framework which includes, as an essential component, a new program on large lake studies. The mission would be to assist in maintaining the ecologic integrity of Lake Superior and its watershed by providing the knowledge necessary to guide policy decisions on the use of land and water resources. To achieve this mission, the program should have the following components:

- ***Ecological Research to understand how Lake Superior works and is coupled to its watershed.*** The following areas of research are essential to understanding the Lake:
    - Food chain dynamics from phytoplankton to game fish
    - Biogeochemical Cycling of nutrients, particulates and toxic substances
    - Material Transport through circulation, ventilation, resuspension and atmospheric deposition
    - Impact of climate change on the lake
    - Coupling of Lake Superior to its watershed
- ***Assistance to Lake and Water Use Planning***
- ***Policy Analyses***
- ***Transfer of Knowledge***

The second phase of the initiative has been supported by the LCMR and contracted to the Stanford Research Institute (SRI). This phase dealt with identifying the administrative structure(s) that would be most effective in fulfilling the overall goal of bringing research on Lake Superior into policy decisions.

SRI International has now submitted their final report which outlines several key components for a successful program.

- An Institute for Lake Superior Research (ILSR) should be developed at the University of Minnesota.
- The headquarters for the ILSR activities should be in Duluth, Minnesota.
- The organizational structure should incorporate a "core" program with a "matrix" structure.
- A top quality academic research initiative should be developed in conjunction with a graduate training program through the University of Minnesota Graduate School.

The All-University effort that is described will engage state, federal and Canadian agencies in coordinated efforts to address the current inadequate knowledge base that will be necessary to anticipate the consequences of Lake-wide changes.

PHYSICAL, CHEMICAL, AND ECOLOGICAL ISSUES ON LAKE SUPERIOR. **Steven J. Eisenreich**, Environmental Engineering Sciences, Department of Civil and Mineral Engineering, University of Minnesota, Minneapolis 55455.

Lake Superior contains 10% of the earth's surface water reserves, about 50% of the water in the Great Lakes, is a major economic and recreational asset to the region, and is a natural resource of immense value. Lake Superior will require diligent stewardship to maintain and protect its pristine nature under future development and global change pressures. The challenges for the foreseeable future relate to the environmental condition of the lake, a challenge requiring an inter- and multidisciplinary research endeavor. In 1989, a four-member panel of distinguished scientists chaired by Professor Thomas Johnson (Duke University Marine Laboratory) presented the research issues facing Lake Superior in the interdisciplinary framework of Climate Change, Biogeochemical Cycling, Material Transport, and Food Web Dynamics. This presentation will focus on these four areas as viewed from the perspective of a scientist who has worked on and in the lake for nearly 15 years.

Climate change is coming (or is it already here - drought of 1986-90). Most experts agree that greenhouse gases, mainly CO_2 and CH_4, are increasing in the atmosphere, and that climate warming will occur. The big questions relate to when, where, and how much? The prevailing wisdom indicates that the Lake Superior region will be warmer and drier, but the truth is far from certain. Lake Superior will experience warmer waters, lower lake levels, reduced outflow to the lower lakes, possibly higher levels of biological activity and nutrient turnover, and pressure for diversion. Lake Superior offers a prime setting for monitoring long term trends associated with climate change. To monitor the lake for change requires a concerted effort to understand the physical, biological and chemical processes in the lake, and how these natural processes combine to influence water quality. insufficient research has been performed on Lake Superior to adequately describe the fundamental processes controlling chemical and biological composition, much less how a changing climate and increased development in the basin will affect its composition and quality. A significant need exists to begin gathering the necessary data to understand how elements and compounds cycle in the lake, how transport processes drive the movement and fate of the chemicals, the flows of energy through the aquatic food web, and the dynamics of organism populations at all levels in the ecosystem. One thing is known for sure, development and change in the lake's watershed will increase the input of elements and chemicals. We need to be in a position to monitor trends in ecosystem quality and predict changes in the system. This will ultimately permit us to better manage the entire lake ecosystem to preserve it for future generations.

SECTION 2. Current Issues in Water Supply and Drinking Water Treatment: State Suite; Organizers: M. Semmens, Dept. of Civil & Mineral Engineering, Univ. of MN, and R. Clark, MN Dept. of Health

1:20 Opening remarks: M. Semmens and R. Clark

1:30 D. Schuler, St. Paul Water Utility, St. Paul. *Impact of reservoir management on treated water quality.*

1:55 T. Field, Bonestroo & Assoc., St. Paul. *The impact of new drinking water standards on the future cost of water.*

2:20 M.A. Deady and G.D. Keil, Barr Engineering, Minneapolis. *Using contaminated water for potable supply.*

2:45 B.M. Olsen, MN Dept. of Health, Minneapolis. *Wellhead protection for Minnesota's 17,000 public water supply wells.*

3:10 Refreshment Break

3:30 L.D. Gust, MN Dept. of Health, Minneapolis. *Development of drinking water standards for groundwater protection.*

3:55 R. Lively, MN Geological Survey, St. Paul. *Radium geochemistry and current research on radium in the Mt. Simon/Hinckley aquifer of southern MN.*

4:20 C.L. McLain, Moorhead Public Service Department, Moorhead. *Moorhead's efforts to improve water treatment and supply.*

4:45 Discussion and questions

IMPACT OF RESERVOIR MANAGEMENT ON TREATED WATER QUALITY

David Schuler, Chemist, St. Paul WAter Utility, 85 E. Vadnais Blvd., Vadnais Heights, MN 55079.

The St. Paul Water Utility (SPWU) receives source water from a chain of impoundment reservoirs that are fed mainly by diversions from the Mississippi River, the Rice Creek Watershed, and by runoff from local watersheds. In the recent past, the SPWU has been troubled by severe taste and odor problems due to the rapid development of the watershed and subsequent deterioration of lake water quality. Intensive lake and watershed studies were undertaken starting in 1984 to identify causes and remedies. Early phases of the study identified the basic problem of nutrient enrichment and targeted important phosphorus sources, (Mississippi River diversions, local watershed runoff and recycling from the lake sediments) for remediation. Control measures implemented by the SPWU include: 1) selection of supply sources based on chemical considerations (phosphorus, iron, silica); 2) phosphorus inactivation by ferric chloride injection at the Mississippi River and Lambert Creek (a major phosphorus source); 3) construction of regional and on-site detention ponds to reduce the phosphorus load from the urbanized watersheds; 4) hypolimnetic aeration of Vadnais Lake, coupled with ferric chloride feeds to reduce phosphorus recycling from sediments. Recent improvements in water quality have resulted in the reduction of taste and odor incident frequency, decreased production of trihalomethanes and lower chemical costs at the treatment plant.

THE IMPACT OF NEW DRINKING WATER STANDARDS ON THE FUTURE COST OF WATER

Ted Field, Project Engineer, Bonestroo and Associates, 2335 Highway 36, St. Paul, MN 55113.

The new federal drinking water standards will increase the level and cost of water treatment for U.S. water utilities. Public health, rather than aesthetic concerns, will prevail most often as the reason municipalities upgrade their treatment systems. Municipalities will bear responsibility of protecting consumers from various harmful contaminants found in water sources at low concentrations.

On a large scale, the cost of producing safe drinking water will increase; to small communities, costs may be prohibitive to the point that compliance with the rules will involve seeking exemptions. The new standards will also increase the responsibilities of engineers and laboratories. Engineers will be challenged to apply advanced treatment technologies in ways that are affordable to utilities. Laboratories will not only analyze contaminants at much lower detection levels than before, but must minimize the variability of its results.

USING CONTAMINATED WATER FOR POTABLE SUPPLY

Mark A. Deady, P.E. and Gregory D. Keil, P.E., Barr Engineering Company, 7803 Glenroy Road, Minneapolis, MN 55435.

Several Twin Cities suburbs, and an increasing number of communities around the country, have been forced to deal with the loss of their potable water supply as a result of groundwater contamination by industrial chemicals. The community is faced with the decision of developing an alternative water supply or treating the contaminated supply. The party responsible for the contamination, on the other hand, is most often faced with mitigating or remediating the damage resulting from the contamination. For contaminated groundwater, this is often accomplished by controlling future contaminant migration with groundwater extraction. This typically requires treatment and disposal of the extracted groundwater.

The presentation will include a discussion of how, in some instances, the use of contaminated groundwater for potable supply can provide solutions to several of the problems faced by affected communities and responsible parties. The relationship required between affected and responsible parties to solve these problems is unique. Several case studies will be described to demonstrate issues that must be addressed in utilizing contaminated groundwater for potable supply. Some of these issues include balancing the requirements for potable supply with the objectives of the remedial action, public perceptions, and considerations for treatment technology selection and operation.

WELLHEAD PROTECTION FOR MINNESOTA'S 17,000 PUBLIC WATER SUPPLY WELLS.
Bruce M. Olsen, Minnesota Department of Health, 925 S.E. Delaware St., Minneapolis Mn. 55440.

The fundamental goal of wellhead protection (WHP) is to protect public wellhead areas from contaminants that may have an adverse effect on human health. A public water well is one that has at least 15 service connections or serves at least 25 people for six months out of a year. Minnesota has about 17,000 public water supply wells. Preventing these sources of potable water from becoming contaminated is a difficult task and one that has not always been accomplished successfully. For example, in a 1982-1985 study of volatile organic compounds (VOCs) in community water supplies, the Minnesota Department of Health (MDH) reported that of 1,801 community wells tested 109 or 6.1 percent had detectable levels of VOCs. In order to achieve long-term protection for public wells, Minnesota is developing a WHP program.

WHP measures center around controlling sources of contamination in the area that contributes water to a well over a specified time period such as ten years. A WHP area is defined using geologic and hydrologic criteria; such as the physical characteristics of the aquifer and the effects a pumping well has on the rates and directions of groundwater movement. A management plan is developed for the WHP area that includes inventorying potential sources of groundwater contamination, monitoring for the presence of specific contaminants, and implementing the approach to managing sources of contamination that present a threat to the aquifer being used by the public supply well. The approach to controlling sources includes education, technical assistance and financial assistance in addition to any regulatory measures deemed necessary.

The Minnesota Groundwater Protection Act of 1989 mandates that the Commissioner of Health develop WHP measures for public wells. Furthermore, the Governor has designated MDH as the lead agency to develop the State's approach to WHP as required by the 1986 Amendments to the federal Safe Drinking Water Act. MDH expects to implement WHP for public wells in 1992. Although MDH is the lead agency, the successful implementation of WHP depends on the cooperation of local and State governments, public water purveyors, and the general public.

WHP is a good concept but one that will be difficult to pursue if it is not developed carefully. The diversity of hydrogeologic settings and local complexities in groundwater movement will complicate how Minnesotans develop criteria and methods for assigning boundaries to WHP areas. Also, the legal and financial implications of controlling or eliminating existing and proposed sources of contamination in WHP areas must be evaluated in order to effectively and equitably implement wellhead protection controls. Finally, the approach to public education and the outreach capabilities needed to obtain public support for WHP controls must be carefully considered if Minnesota is to have a successful WHP program.

MDH is establishing two ad hoc advisory groups to assist in developing State WHP rules. A technical advisory group will consider the hydogeologic criteria and methods for delineating WHP areas. A policy advisory group will consider procedures for implementing WHP and coordinating it with the State's other groundwater protection programs. Furthermore, the policy group will suggest methods for phasing in WHP for the State's 17,000 public water supply wells. The recommendations from each group will be considered by MDH as it prepares State WHP rules MDH in early 1991.

Several communities are already establishing WHP management strategies for their well fields. The Clean Water Partnership Program administered by the Minnesota Pollution Control Agency provides financial and technical assistance for most of these efforts. MDH is providing staff support and views these projects as a means to gain valuable experience with implementing WHP and assessing the needs of local governments and public water purveyors.

THE DEVELOPMENT OF HEALTH BASED STANDARDS FOR GROUNDWATER CONTAMINANTS. <u>Larry D. Gust</u>, Minnesota Department of Health.

The goal of the 1989 Minnesota Groundwater Protection Act is to maintain the State's groundwater in its natural condition, free from any degradation caused by human activities. A provision of this Act provides authority to the Commissioner of Health, Minnesota Department of Health, to promulgate health risk limits for substances degrading the groundwater.

The health risk limits will be adopted by rule. There is also a provision that allows the adoption of emergency limits if the Commissioner determines that emergency conditions exist endangering public health and welfare. Emergency limits are effective for one year.

The Act stipulates the use of U.S. Environmental Protection Agency risk assessment methods to derive the health risk limits. For toxicants that are not carcinogens the limits will be derived using a reference dose, an uncertainty factor, a drinking water equivalent, and a factor for relative source contribution. For toxicants that are considered known or probable human carcinogens, the adopted health risk limits will be derived from a quantitative estimate of the chemical's cancer potency value obtained from the U.S EPA's Carcinogen Assessment Group.

The Act specifies that each adopted health risk limit will be reviewed at least every four years. However, considering the rate at which new data are added to the toxicologic databases of many chemicals, the rule will very likely require a more frequent review of the limits.

The rule will be written by the Department's Section of Health Risk Assessment. This Section has gained considerable risk assessment expertise in setting exposure guidelines during the development of the Department's "Recommended Allowable Limits for Contaminants in Drinking Water" (RALs). The RALs, which are nonregulatory exposure guidelines, have been used by the Department since 1986 to evaluate the potability of unregulated water supplies (i.e. private wells). The Act provides a mechanism for adopting existing RALs through a specified notification process.

A notice of solicitation of outside information or opinions with respect to health risk limits for groundwater was published in the January 22, 1990 <u>State Register</u>. The Minnesota Department of Health welcomes all inquires and comments, which may be directed to:

David G. Gray
Minnesota Department of Health
Division of Environmental Health
925 S.E. Delaware Street
P.O. Box 59040
Minneapolis, Mn 55459-0040

RADIUM GEOCHEMISTRY AND CURRENT RESEARCH ON RADIUM IN THE MT. SIMON/HINCKLEY AQUIFER OF SOUTHERN MINNESOTA. Richard S. Lively, Minn. Geological Survey, 2642 University Ave., St. Paul, MN 55114

Recent monitoring of public and community water supplies under the Safe Drinking Water Act has shown that water obtained from deep aquifers in Minnesota can exceed the current standards for radium content. Under current standards, drinking water is not to exceed 5 pCi/L of combined activity from ^{226}Ra and ^{228}Ra.

Radium is a naturally occurring radioactive element produced during the radioactive decay of uranium and thorium in the Earth's crust. As a result, radium is found in rocks, soils, springs, and ground water. Two isotopes of radium are regulated under the Safe Drinking Water Act and are being measured in this project. Radium-226 is produced by radioactive decay within the ^{238}U decay series and ^{228}Ra is produced in the ^{232}Th decay series. Radium-226 decays by alpha emission and ^{228}Ra decays by beta emission. The half-life of ^{226}Ra is 1600 years and of ^{228}Ra is 5.8 years.

Although radium is an alkaline earth and has a chemical behavior similar to that of Ca, Sr or Ba, it is present in such low concentrations that adsorption is much more significant in determining distribution than solubility. Radium in ground water poses an increased risk of bone cancer due to ingestion, if elevated levels are consumed over a lifetime.

Research currently in progress involves sampling of the major deep aquifer in southern Minnesota, the Mt.Simon/Hinckley, for radium, age, and chemical and radiological characteristics. The study is designed to identify the areal distribution of radium within the Mt.Simon/Hinckley aquifer and correlate that with chemical parameters and age of the water. We will also be evaluating whether or not the radium levels in the water are related to variations of near-surface and bedrock geology. For instance, buried bedrock valleys that allow recent water to enter deep aquifers could dilute radium concentrations locally.

To date, 34 out of an anticipated 80 analyses have been obtained. Chemical and chronometric data are similar to those obtained from previous studies of the Mt.Simon/Hinckley aquifer, indicating that the ground-water system is stable. The radium results show that two-thirds of the samples exceed the EPA limits for combined ^{226}Ra and ^{228}Ra activity. In the samples measured, the average activity of ^{226}Ra is 4.9 ± 3 and ^{228}Ra is 5.1 ± 3. The $^{228}Ra/^{226}Ra$ activity ratio (A.R.) is 1.15 ± 0.40. This activity ratio implies that the radium is supported by uranium and thorium in the rock (A.R. Th/U in crust = 1.2). However, the large standard deviation of average activities implies that uranium and thorium are not uniformly distributed within the aquifer.

High radium content in an individual well does not necessarily indicate that a water supply system exceeds the limits of the drinking water standard. A water system may have only one well that has elevated radium among several that do not.

This research is being supported by an appropriation in the Groundwater Bill of 1989 (SF 262) to the Department of Natural Resources, contracted to the Minnesota Geological Survey.

MOORHEAD'S EFFORTS TO IMPROVE WATER TREATMENT AND SUPPLY

Clifford L. McLain, Moorhead Public Service Dept.,
P. O. Box 779, Moorhead, MN 56561-0779

The City of Moorhead obtains its water supply from the Red River of the North and the Moorhead and Buffalo Aquifers. The Red River experiences near zero flows during drought conditions. The water quality in the river is very poor for several periods each year. Groundwater supplies are limited within the area. The peak water demand has exceeded the water treatment plant capacity due to growth within the city. The water treatment plant must be upgraded to meet the new standard for disinfection byproducts under the SDWA.

Long-range planning for capital improvements began in 1985. Capital improvement projects identified in 1985 to meet increased water demands and new SDWA standards required doubling of water rates. A consumer task force reviewed the plans and revenue requirements. A gradual increase in water rates over a seven- to nine-year period was recommended. Several capital improvement projects have been completed to date, which include a new well field, additional finished water storage reservoirs, and new transmission pipelines.

A master plan has been developed, which identifies future capital improvements and estimated costs. Revenue requirements have been identified. The required increases in water rates and an estimated schedule for bond sales have been developed. Long-range planning has resulted in a plan to meet Moorhead's present and future water needs without causing rate shock to our customers.

SECTION 3. **Building Institutions to Manage Water Across Jurisdictional Borders and Cultural Boundaries:** Minnesota West Ballroom; Organizer: L.P. Gerlach, Dept. of Anthropology, Univ. of MN

1:20 Opening remarks: L. Gerlach

1:30 L.P. Gerlach, Dept. of Anthropology, Univ. of MN, Minneapolis. *The problems and prospects of institutionalizing ecological interdependence in a world of local independence.*

1:55 S. Keefe and D.O. Renz, Metropolitan Council, St. Paul. *Managing water across the Metropolitan Twin City Area: A challenge in regional cooperation.*

2:20 M.C. Brand, Environmental Quality Board, Water Resources Committee, St. Paul. *Citizen participation in water management at the state level: the challenge and the reality.*

2:45 K.W. Easter, Dept. Agriculture & Applied Economics, Univ. of MN, St. Paul. *Institutional arrangements for managing water conflicts.*

3:10 Refreshment Break

3:30 D. Larson, Westmoreland, Larson, Webster Inc., Duluth. *Communication and cooperation to foster stewardship of freshwater: an example of transborder institution building.*

3:55 P.B. Landers, Environmental Education Board, State Planning Agency, St. Paul. *Citizen action for creating environmental institutions: the Environmental Education Act of 1990.*

4:20 D. Sharp, U.S. Office for the North American Waterfowl Management Plan; *Cooperating for wetlands and wildfowl management: the North American Waterfowl Management Plan.*

4:45 Discussion. R.S. Bolan, Humphrey Institute of Public Affairs, Univ. of MN, Minneapolis, discussion leader. Participants will be asked to submit question cards at break and before open discussion.

THE PROBLEMS AND PROSPECTS OF INSTITUTIONALIZING ECOLOGICAL INTERDEPENDENCE IN A WORLD OF LOCAL INDEPENDENCE. **Luther P. Gerlach, Department of Anthropology, University of Minnesota, Minneapolis, MN 55455**

Management Mismatches and Institutional Dilemmas. Humans in urban-industrial society are learning that the institutions (sociocultural) they have established to attain and utilize natural (biophysical) resources do not match the usually much larger scales and longer time spans over which these environmental systems work. From the atmosphere to aquifers, grasslands to wetlands and the migratory ranges of wildfowl, ecosystems cross jurisdictional borders and cultural boundaries. They certainly pay no heed to such hallowed time frames such as the quarterly business report and the biannual decision and funding cycles of legislatures. Indeed, they care not that humans usually don't live beyond 80 years, barely think of ancestors beyond two generations and greatly discount the future. The "eco-" systems of biology and physics run on scales and clocks different from those humans use.

Humans are also learning that the scientific methods and other sociocultural institutions they have established to solve the problems of the interaction between humans and environment do not match the complexities of these ecological interactions. Urban/industrial society has been organized around scientific methods which rely on atomistic dissection of events to determine their causes, effects and linear progression, and from this it agrees upon solution. But people are learning that in the feedback systems of real life, solutions cause new problems. They are increasingly demanding that consequences which were formerly disregarded as externalities now be recognized and incorporated as responsibilities.

Yet, people are limited in their ability to implement a systems approach, in part because the sectors of industrial society have a very compartmentalized and specialized division of labor. No sector is effectively organized to cooperate laterally, across levels and departments. Leaders in industry and business and their organizational consultants recognize that this limits productivity, and they are seeking remedy by experimenting with various quality circles and matrix organizations. Academics recognize this in their persistent call for truly interdisciplinary research, but have as yet not been able to institutionalize reward structures for such effort. Government officials recognize this in episodic efforts to build inter-agency cooperation, but again these efforts are greatly constrained by traditional rewards and jealousies.

The need for new institutions has been usefully glossed as institutionalizing ecological interdependence. Contributors to a project on sustainable development of the biosphere held at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria explained why it is necessary to accomplish this in ways which become integrated with the already well institutionalized economic interdependence (Brooks, Clark and Munn 1986). But these scholars do not explain how this is to be accomplished, nor in particular do they explain how interdependence is to be reconciled with another highly valued goal, protecting and advancing the opportunities and liberties of people organized to interpret events more locally and particularly, according to perspectives which can be usefully summarized as "ethnolocal independence."

We live in a world in which such independence is honored, desired, growing as ever more important. The need to institutionalize interdependence in ways which build from rather than tread on local independence is glossed as "thinking globally, but acting locally." This slogan suggests that part of the approach lies in a way of thinking, of thinking about consequences. This can be summarized as the construction of a culture of common interest. The slogan points to a direction for change; it does not explain how this change is to be done.

Steps to Matching Problem and Response. One important contribution to answering this question has been forthcoming from the work of a growing number of social scientists exploring how societies have or have not been able to build arrangements to avert resource mismanagement of the type known as the "tragedy of the commons" (Hardin 1968), and to instead, institute workable common property arrangements. These scholars, many of them anthropologists, have been able to show how small scale societies, many of whose members often interact face-to-face, have built such arrangements (McCay and Acheson 1987). Lacking are studies of how large scale societies have succeeded or failed to accomplish this (Ostrom 1987). Even less studied is how two or more large societies, or nations, have collaborated to identify and manage common resources, although there is some promising new research on efforts to co-manage the atmosphere and the seas (Haas in press, Lipschutz 1989).

Particularly needed is information about management efforts which are large enough in scale to help us learn about global management, but small and tight enough to be studied. Water quality and quantity management events in Minnesota, and in Minnesota's connections with other states/provinces and nations through the Great Lakes, the Mississippi and Red Rivers, and the management of the North American wildfowl flyway all offer such information. Learning about these is important in its own right, but also because it provides information which can be transferred to help us understand the general problems of institutionalizing ecological interdependence in a world of local independence. I offer a conceptual framework to think about processes of building institutional responses to resource management mismatches and cultural dilemmas.

BIBLIOGRAPHY

Brooks, Harvey
1986 "The Typology of Surprises in Technology, Institutions, and Development," in Clark, W. C. and R. E. Munn, eds., Sustainable Development of the Biosphere, Cambridge University Press, Cambridge, New York, pp. 325-348.

Clark, W. C. and R. E. Munn
1986 Sustainable Development of the Biosphere, Cambridge University Press, Cambridge, New York.

Hardin, G.
1968 "The Tragedy of the Commons. " Science vol. 162: pp.1243-48.

Lipschultz, Ronnie D.
1989 "Bargaining Among Nations: Cult, History and perceptions in Regime Formation." paper presented at the workshop: Managing the Global Commons: decision Making and Conflict Negotiation in Response to Climate Change, August 1-4, 1989, Knoxville, TN.

McCay, Bonnie J. and James M. Acheson, eds.
1987 The Question of the Commons: The Culture and Ecology of Communal Resources. Univ. of Arizona Press, Tucson.

Ostrom, Elinor
1987 "Institutional Arrangements for Resolving the Commons Dilemma: Some Contending Approaches." in McCay and Acheson, eds., The Question of the Commons: The Culture and Ecology of Communal Resources. Univ. of Arizona Press, Tucson, pp. 250-265.

MANAGING WATER ACROSS THE METROPOLITAN TWIN CITY AREA: A CHALLENGE IN REGIONAL COOPERATION.

Steve Keefe and David O. Renz, Metropolitan Council, St. Paul, MN 55101

Water is a critical element of the Twin Cities region's much lauded quality of life, as well as its economic success. But the effects of recent years' weather cycles, and especially the 1988 drought, have increased the visibility of water resources management problems. This is particularly true for state, regional, and local policy makers as they grapple with issues and interests that cross many jurisdictional boundaries.

The Metropolitan Council believes that there needs to be a more systematic approach to the management of the region's water resources. Current management efforts are fragmented and tend to treat different aspects of water management as if they were independent when, in fact, they are very closely intertwined. This fragmentation has tended to result in the separation of supply and quality issues, surface and groundwater issues, and point source and nonpoint source pollution issues. The Council believes that the most appropriate agency to coordinate planning for the whole Twin Cities water system is the Metropolitan Council itself, partly because it is involved in most aspects of water planning now, and partly because land use issues for which the Council also coordinates planning are so relevant to the management of the water system.

However, the Council also believes that the benefits of Council control over water management activities in the Region need to be balanced against two other important aspects of the Council's mission; first, the importance of keeping the Council out of implementation activities that might distract it from its central strategic long-range planning mission and, second, the important value of minimizing regional intrusion on local autonomy and freedom to pursue diversity.

There appears to be a growing appreciation for the need for some systematic approach to this complex issue, and there is some reason to hope that the political conflicts that have existed in the past over who should be in control of these matters can be resolved or effectively managed in the next several years. To do so in ways that are responsive to the needs of the regional water system and the values and interests of all of its stakeholders is a key leadership challenge for the Council.

CITIZEN PARTICIPATION IN WATER MANAGEMENT AT THE STATE LEVEL: THE CHALLENGE AND THE REALITY

Martha C. Brand, Citizen Member, Minnesota Environmental Quality Board,
Chair, Water Resources Committee.

A limited look at two of the ways citizens participate in the management of Minnesota's water resources was conducted. The inquiry concentrated on two government bodies in which citizens were members; one group was formed in connection with the passage of the Minnesota Groundwater Protection Act -- the Environmental Quality Board's (EQBs) Citizen's Advisory Board -- and one was the EQBs Water Resources Committee which was active in the passage of the Act but also has ongoing water management responsibilities.

The two bodies were analyzed for composition, goals, successes and problems, as well as the appropriateness of having citizens in such roles. The conclusions were that citizens can play an important role in managing water resources in the state, but that "success" may depend on such factors as the ratio of citizens to government personnel, the duration of the management project, the staff support given to the citizen members, and the knowledge of the citizens about the water management generally. It was felt that any inefficiencies resulting from citizens participating in management were more than overcome by the addition of a different perspective on water management and a view divorced from inter-agency politics.

INSTITUTIONAL ARRANGEMENTS FOR MANAGING WATER CONFLICTS IN MINNESOTA. K. William Easter, Professor, Department of Agricultural & Applied Economics, University of Minnesota, St. Paul, MN.

Where there are people, there is water--and conflict over water. In the upper Midwest, conflicts between use sectors, such as agriculture, industry, urban water supply and sanitation, fishery, navigation, environmental preservation and recreation are becoming increasingly acute because of our dry conditions combined with growing concern for environmental quality. The severity of these conflicts is aggravated by lags in the development of institutions governing water use.

Many, perhaps most, of these conflicts over water quality and quantity will be resolved politically, guided by economic values and economic and social institutions. This paper briefly reviews some of the growing conflicts over water use in Minnesota and considers different institutional arrangements and policy tools which could be of use in conflict management, including market and government approaches as well as action by water users.

Water pollution costs have led to a number of conflicts in Minnesota. First was the conflict between industrial and municipal polluters and recreational water users. In response to this conflict, many billions of dollars have been spent on programs to install and improve municipal treatment facilities. Second is the growing conflict between farmers and recreational water users. This conflict not only influenced the U.S. farm bill, but has spawned programs in Minnesota such as RIM. Third is the conflict between farmers and users or potential users of groundwater. As measurement of water quality has improved, it has become evident that agriculture is polluting groundwater with herbicides and nitrates. Finally, there is a growing potential for conflict among states over pollution control regulations. Will states with strong environmental regulations lose their competitive edge to states with few regulations?

Conflicts also arise particularly in dry periods when water withdrawals are large and supplies are low. Good examples of such conflicts include the following. First was the 1988 conflict between the Twin Cities and those living around the northern lakes over the release of lake water to increase the flow in the Mississippi River. Only a timely rain dampened this conflict. Second was the conflict between users of Lake Minnetonka and those using groundwater, over pumping groundwater to raise the lake level. Third was the 1988 conflict among Great Lakes states over the release of Lake Michigan water into the Chicago river to increase stream flows downstream. Thus conflicts arise between recreational and agricultural water users, between north central and southern Minnesota water users, and between Great Lakes states. These conflicts will certainly reoccur during dry periods, unless institutional arrangements are developed to help resolve them.

COMMUNICATION AND COOPERATION TO FOSTER STEWARDSHIP OF FRESHWATER: AN EXAMPLE OF TRANSBORDER INSTITUTION BUILDING Donn Larson, Chairman, Westmoreland Larson & Webster Inc., Member of the Board of Directors, Lake Superior Center

Lake Superior Center is a non-profit corporation formed in March 1989 to build and operate an international freshwater education complex at Duluth, Minnesota. The Center's mission is unique in North America: interpretation of freshwater values and issues through the lens of Lake Superior and other large lakes of the world.

The Center's exhibits, freshwater aquarium, training programs, international conferencing and comparative lakes program will provide international focus on the special role that large lakes play as monitors of environmental change.

The Center's original intention was to build an interpretive complex on the Duluth waterfront. But response to the announcement revealed a much more significant latent need for a freshwater educational force of national and international importance.

Residents of the Lake Superior basin rallied in support of the idea, soon to be joined by business, government and conservation leaders of the state of Minnesota, neighboring states, the U.S. and Canada, and by September, the Soviet Union.

Governor Perpich pledged state support, and Minnesota's senators and 8th District Congressman James Oberstar gave early encouragement and advice. The U.S. Environmental Protection Agency, World Resources Institute, Great Lakes Commission, University of Minnesota, National Wildlife Federation, Natural Resources Council, and leaders of several prestigious foundations and other conservation groups offered help.

Founders of the Center concept discovered growing consensus toward a need to establish a place for freshwater--a lodestar that shows the way to understanding the world's freshwater resource through knowledge of the world's large lakes, and inspires the personal stewardship needed to preserve them.

By the end of 1989, Lake Superior Center became programs as well as exhibits, a forum as well as a facility, and it became international.

In September, Center President Bob Bruce, Mike Lalich, director of the University of Minnesota's Natural Resources Research Center, and Don McNaught, director of the Minnesota Sea Grant program, discussed collaborative programs with Soviet officials at Lake Baikal in the Soviet Union. Center Chairman Nick Smith made high-level contacts with the Soviet government in October and returned to Moscow in January for additional talks in conjunction with an environmental conference.

In January protocols were signed between Lake Superior Center and the Soviet Ecological Union of Enterprises and Associations, and between Lake Superior Center and the Ecological World of Baikal of the Republic of Buriat, a Division of the Academy of Sciences of the USSR. Two other agreements are pending, including a protocol with the Limnological Institute of the Siberian Branch of the Academy of Sciences.

Four influential Soviet citizens have accepted seats on the Lake Superior Center Board: Sergey Bachurin, Institute of Physiologically Active Substances, Academy of Sciences; Andrei Malenkov, chairman of the Ecological Union of Enterprises and Associations, a non-state association formed under the Ecological Committee of the Supreme Soviet; Alexey Yablokov, deputy chairman of the Ecological Committee of the Supreme Soviet; and Shapkhaev Gerasimovich, Peoples Representative of the District of Buriat, which encompasses 80 percent of Lake Baikal.

Current projections reveal that $30--$35 million will be required to complete the facility, to come from a combination of public and private sources. Over $2 million, mainly private gifts, has already been invested in acquiring a site and in design and planning. The Center is scheduled to open in May 1994. Programming will begin independently prior to construction; an October 1990 conference is expected to draw about 30 U.S. and Canadian and 10 Soviet scientists.

The earth's major lakes are essential freshwater resources, vital ecosystems, and valuable barometers of environmental change. The founders of Lake Superior Center in North America, by reaching out to receptive people in the Soviet Union, are helping to ensure that those nations responsible for nearly half of the world's freshwater, serve as conscientious stewards of that resource.

CITIZEN ACTION FOR CREATING ENVIRONMENTAL INSTITUTIONS: THE ENVIRONMENTAL EDUCATION ACT OF 1990. **Pamela B. Landers, Minnesota Environmental Education Board, State Planning Agency, 300 Centennial Building, St. Paul, MN 55155**

In the preindustrial eras, people knew they as individuals depended on the plants and animals which sustained them but they were not aware that countless individual decisions could jeopardize the survival of their species. The inventive brain, that is the human species' means of controlling its environment provided ever-more sophisticated methods of manipulating environmental elements. The environment seemed to provide a limitless source of materials and energy for human use; it was a stage for human performance. There was little consciousness of limitations and little need for one as long as the human population remained low and use of the resources did not strain their abilities to handle the load.

However, populations grew, use of the resources expanded, and methods of collecting scientific data became more sophisticated. We find now that individual actions of this species taken all together are affecting the life support systems of this planet. Awareness of individuals that their actions taken to further their own interests may in some way be affecting the survival of both themselves and their descendants is necessary before it will be possible for people to accept that we must make decisions about which of those individual actions should be changed and in what way.

In the September, 1989, Scientific American, William D. Ruckelshaus, former administrator of the Environmental Protection Agency, states that we are moving toward "a modification of society comparable in scale to only two other changes; the agricultural revolution of the late Neolithic, and the Industrial Revolution of the last two centuries. Those revolutions were gradual, spontaneous and largely unconscious. This one will have to be a fully conscious operation..."(3)

One of the major methods for bringing about this conscious revolution is environmental education. In What Makes Education Environmental? J. C. Smyth states "the cornerstone of environmental education is (helping the individual to identify) with the environment as inseparable and interdependent parts of a single entity".(1)

This state, the nation and many nations of the world are being galvanized to institutionalize or mainstream environmental education. In the last century and the early part of this one, nature study was the province of a wealthy or very interested few and did not appear to be connected to the rest of human endeavors. During the dustbowl days, conservation education was the province of agriculturalists and the hunting and fishing groups. In the late '60s, scientists studying the world resources and population became alarmed enough to publicize their findings by means of books and media. In the late '70s, the federal government supported the beginning of environmental education on state levels by supplying grants to states that would write environmental education plans. In a few states, including Minnesota, the plans have been proceeding though often minimally funded.

In most, they disappeared. In the '80s, environmental education received little governmental support. However, it proceeded by means of the efforts of scientists, voluntary groups, agencies whose personnel were becoming increasingly aware of the need and naturalist organizations. Agencies that carried out some sort of environmental education programs often did so under the guise of planning, since education positions were among the first to be cut in tight revenue years. Since the first earth day of 1970, most environmental education has been delivered by means of informal mechanisms.

The number of groups, organizations, agencies, and institutions other than governmental ones interested in delivering an environmental education message is growing exponentially. These efforts have been expanding at the same time that major discoveries have been made and publicized about the state of the planetary support system.

In Minnesota, citizens who traditionally want less government rather than more are demanding that heretofore unresponsive government bodies create governmental institutions to disseminate environmental education as well as environmental regulation. The environmental education efforts of these nongovernmental groups, organizations and media have brought citizens to accept that ordinary people in their everyday lives have heavy impacts on the resources. It is not a case of a few wrongdoers whose incarceration will solve the problems. In a democracy, it is not possible to create sweeping behavioral changes by decree.

Citizens have recently made these demands clear in three ways, first by overwhelmingly passing an environmental trust fund with a 75% majority; secondly, by strongly voicing their opinions that environmental education should be included in the programs financed by the environmental trust fund, even though the trust fund authors and administrators had no intention of including it, and thirdly, by helping to design and push through the legislative process, the Environmental Education Act of 1990.

The result of this effort is one of the final steps in institutionalizing a particular world view in the state of Minnesota.

COOPERATING FOR WETLANDS AND WATERFOWL MANAGEMENT: THE NORTH AMERICAN WATERFOWL MANAGEMENT PLAN. David E. Sharp, U.S. Office for the North American Waterfowl Management Plan, Twin Cities, MN 55111.

The North American Waterfowl Management Plan was signed May 14, 1986 by the Minister of Environment for Canada and the Secretary of Interior for the U.S. The Plan is a basic policy document with which all people, public and private, who are interested in wetlands and wetland-dependent wildlife can identify. It establishes recognition by the United States and Canada that the North American waterfowl resource is of significant international importance and its conservation must be pursued through cooperative planning and management.

The Plan has a 15 year horizon, through the year 2000, with review and updating at 5-year intervals. It does not replace the Flyway Council System or related federal/provincial cooperative management systems now in place, nor does it alter processes used in each country to establish cooperative management programs and regulations governing the harvest of waterfowl, Existing agency budget processes will provide funding for related development, management and research requirements.

<u>Objectives</u>: The Plan sets waterfowl population objectives for ducks of 62 million breeders and a fall flight of 100 million birds - a level common to the decade of the 1970's. In addition, winter objectives for 6 million geese and 150,000 swans were established. To achieve these objectives, the Plan identifies the most important wetland and associated habitats in the two countries and calls for their conservation and management. Specific habitat objectives for the U.S. are to protect and improve an additional 1.1 million acres of production habitat in the north central states; 686,000 acres in the Lower Mississippi Valley and Gulf Coast; 80,000 acres in the Central Valley of California; 50,000 acres along the Atlantic Coast; and 10,000 acres in the Lower Great Lakes/St. Lawrence Basin. Objectives for Canada are to protect and improve 3.6 million acres in the Prairie Province and 70,000 acres in the eastern provinces.

<u>Cost</u>: The cost of this ambitious habitat protection and enhancement program is estimated at $1.5 billion, of which $1 billion is designated for habitat protection and improvement in Canada. The Plan established a funding ratio of 25% from Canadian sources and 75% from U.S. sources. Considerable support will be required from the private sector. The Plan is quite specific in that the two governments are not committed to providing all the funds required.

<u>Administration</u>: Implementation of the Plan is administered by a 12-member North American Waterfowl Management Plan committee, composed of 6 members from Canada and 6 from the U.S. Input from the private sector, states, and provinces is through steering committees established by the respective joint venture organizations, and by the Plan Committee. Chairmanship of the committee alternates between the two countries each year. Plan implementation is guided by Canadian and U.S. Executive Directors and their staffs.

Joint Ventures: One of the concepts of the Plan is to implement cooperative actions through joint ventures, in so far as possible. A joint venture brings together a coalition of federal, state, provincial and private sector forces in a concerted effort to protect and enhance waterfowl habitats and populations through specific projects in specific geographic regions by a variety of methods.

Habitat joint ventures may involve protection and enhancement using current and new techniques. Some examples include the traditional acquisition by fee title, perpetual easement, and shorter term easements, and protection by specific lease arrangements. There have been some innovative new arrangements whereby habitat protection and development funds are piggy-backed on other existing programs, i.e., Food Security Act of 1985, to enhance waterfowl benefits further. New programs that encourage changes in land-use practices on private lands to increase wildlife benefits can make substantial contributions. It is important to bear in mind that this is an effort to protect and enhance all important wetland habitats in a given project area by whatever means are available and acceptable. In addition to acquisition and development, such protection might include zoning and altered mitigation practices to reduce habitat loss.

Since the signing of the Plan and the establishment of President Bush's "No-Net-Loss" policy for wetlands, there has been increasing interest in Plan participation by a number of federal agencies such as the Forest Service, Bureau of Land Management, Bureau of Reclamation, and the Department of Defense, including the Army Corps of Engineers. some of the other agencies under the U.S. Department of Agriculture, such as the Soil Conservation Service, agricultural Stabilization and Conservation Service and the Farmers Home Administration are already involved at the local project level. We will be pursuing discussions with them so as to enable these agencies to apply their support and capabilities to whatever they can do best. This will further enhance our partnership approach.

Conclusion: Although the ideas contained within the North American Waterfowl Management Plan took a long time to develop, its signing has inspired a new spirit of cooperation and support between federal, provincial, state governments and the private sector. The passage of the North American Wetland Conservation Act solidifies congressional support and establishes the mechanism to transfer funds across borders. The partnership concept of joint ventures has been well received by the government agencies, private organizations, and individuals interested in the conservation and management of wetland environments. Enthusiasm is high in all circles and the momentum is building as joint ventures are being developed and implemented. It is one of the most innovative approaches to cooperative management that has ever occurred in international resource conservation. It will undoubtedly be the conservation challenge for the reminder of the century.

SECTION 4. Spatial Analyses in Water Resources and their Management: Congress Suite; Organizers: J. Perry, Dept. of Forest Resources, L. Maki, State Planning Agency, and S. Maeder, State Planning Agency

1:20 Opening remarks: J. Perry, L. Maki, and S. Maeder

1:30 N. Troelstrup, Dept. of Forest Resources, Univ. of MN, St. Paul. *Patterns of water quality in southeastern Minnesota: an issue of scale.*

1:55 G. Fanderi, MN Pollution Control Agency, St. Paul. *AGNPS, State non-point source assessment within ecoregions.*

2:20 S. Heiskary, and C.B. Wilson, MN Pollution Control Agency, St. Paul. *The regional nature of lake water quality across Minnesota.*

2:45 C. Johnston, Nat. Resources Research Inst. and U.S. Environ. Prot. Ag., Duluth, N.E. Detenbeck and G.J. Niemi, Nat. Resources Research Inst., Univ. of MN, Duluth. *GIS use for multiple watershed analysis of water quality relationships.*

3:10 Refreshement Break

3:30 G.N. Meyer, and K.L. Harris, MN Geological Survey, St. Paul. *The Anoka sand plain regional assessment - a pilot study.*

3:55 D. Krystosek, Beltrami Soil and Water Conservation District, Bemidji. *Use of GIS in development and implementation of Beltrami County's comprehensive local water plan.*

4:20 J. Piegat, Hennepin Conservation District, Minnetonka. *Groundwater planning in Hennepin County, Minnesota.*

4:45 Discussion and questions

PATTERNS OF WATER QUALITY IN SOUTHEASTERN MINNESOTA: AN ISSUE OF SCALE. Nels H. Troelstrup, Jr., Dept. of Forest Resources, University of Minnesota, St. Paul, MN 55108.

Water quality in Southeastern Minnesota's "driftless area" has been a topic of concern for a number of years. Authors from several agencies have documented the increased water quality risk associated with intensive agricultural development and poor waste management practices over karst geology. These practices have contributed to high nitrate levels, traces of pesticides, bacterial and viral contamination of well waters as well as high nutrient levels, pesticide contamination, high turbidity levels and sediment loads in surface waters of the region. However, the spatial extent of surface water quality problems has not been adequately addressed in previous investigations of water quality within the southeast. While karst conditions do present a greater risk of water quality problems, they may not represent the entire region.

Research was initiated in 1985 to study the influence of riparian land-use practices on the water quality of three watersheds within Fillmore County. Preliminary results of this research supported data from the literature which suggested that geology and land-use were correlated with stream flow variance, nitrate-nitrogen and specific conductance. In addition, in-situ benthic gross primary production and respiration appeared to be influenced by processes operating at a watershed or subregional level.

A extensive stream survey was initiated across Fillmore and Houston Counties during 1988 to further evaluate spatial patterns of water quality in the southeast. This work was conducted to confirm trends suggested from the intensive work on 3 watersheds in Fillmore County (above). We sampled 15 watersheds on 10 dates (5 dates in spring 1988, 5 dates in fall 1988). Watersheds and sampling dates were chosen at random. Variables measured during this survey included stream discharge, stream temperature, specific conductance, nitrate-nitrogen, pH, alkalinity, turbidity and biomonitoring data for the macrophyte and invertebrate communities at each site.

Data from this survey suggest that several monitoring variables are controlled by processes operating at a subregional scale (see Table 1). Although these variables may be found to vary on a local scale, processes determining their limits seem to be controlled on a watershed or subregional level. Stream discharge variance, nitrate-N, alkalinity, specific conductance, percent of EPT (Ephemeroptera, Plecoptera, Trichoptera) in the invertebrate community and Hilsenhoff Biotic Index values all indicated significant trends with distance from the Mississippi River. These trends appeared to be strongly correlated with the characteristics of aquifers contributing to stream flow above each site (i.e., elevation of spring sources) and the aerial coverage of forested land-use within each watershed.

Other commonly utilized monitoring variables seemed to respond to more local reach and riparian-level processes (see Table 1). These variables showed no consistent trend with spring elevations or watershed level land-use practices. Stream temperature, pH, turbidity, macrophyte development on riffles and the relative abundance of several invertebrate functional groups were found to be more highly correlated with reach and riparian-level land-use practices.

Table 1. Water quality characteristics of southeast Minnesota trout streams (n=number of observations).

Parameter	n	Median	Percentile (25%)	(75%)	Scale
Nitrate-N (mg L^{-1})	150	3.4	2.4	5.6	Regional
pH	150	8.02	7.82	8.22	Local
Alkalinity (mg L^{-1} as $CaCO_3$)	150	262	250	284	Regional
Specific Conductance (uS cm^{-1})	149	386	350	440	Regional
Stream Temperature (^{o}C)	149	10.9	8.1	15.0	Local
Stream Discharge CV (%)	15	24.3	13.8	43.6	Regional
Macrophyte Occurrence (%)	60	22.0	4.0	43.8	Local
Hilsenhoff BI	30	3.32	2.57	4.60	Regional
EPT Percent	30	57.3	40.2	71.7	Regional

The results of this work suggest that the driftless area is a heterogeneous region. Aquifers feeding streams and land-use practices change with distance from the Mississippi River, from watershed to watershed, and even within a watershed. Monitoring variables commonly utilized to evaluate water quality are controlled by processes operating on different scales in space and time. Thus, obtaining an accurate representation of water quality in the southeast is probably not possible through studies on one or a few watersheds using a "hodge-podge" of variables. Different patterns of water quality (on different scales) will be observed through different combinations of monitoring variables and temporal monitoring designs. This could lead to a comparison of "apples and oranges" (i.e., the scale(s) of the question may not match the scale(s) of the variables used to answer the question). Utilization of EPA's regionalization protocols and careful consideration of the questions to be answered by monitoring programs will alleviate scale inconsistencies and provide data capable of addressing monitoring and management problems in heterogeneous regions such as southeast Minnesota.

AN ESTIMATE OF NON-POINT SOURCE POTENTIAL. Gary Fandrei and Sylvia McCollor, Minnesota Pollution Control AGency, St. Paul, MN 55155.

Introduction. A map was generated to identify areas in Minnesota that are likely to have non-point source pollution problems. The map does not reflect measurable characteristics, but displays graphically an interpretation of existing land use, geographic, and water quality data.

Procedure. Ecoregions were defined along Minnesota Department of Natural Resources 1979 minor watershed boundaries. Land Management Information Center land use, geographic information, and Minnesota Pollution Control AGency water quality data were summarized for each ecoregion. Using the ecoregion data summaries, maximum R-square improvement stepwise regression models were developed. Based on these models, ecoregion characteristics were identified that were reasonable predictors of water quality. Because of the limitations of the data interpretations, these predictors indicated only positive or negative relationships with water quality parameters.

Seven predictors of water quality were initially identified: forest and cultivation land uses; silt and sand soil types; slopes of 3-6 percent and greater than 6 percent; and stream orientation. Because of perceived similarities in lake and stream water quality response to land use and geographic features and the limitations of the water quality data base in urban areas, lake orientation and urban land use were added as water quality predictors.

Forest land use and sand soil types showed negative relationships to water quality.; The other predictors showed positive relationships.

The water quality predictors for each minor watershed were ranked, based on the percentage of area of each predictor characterized in the minor watershed, and whether or not the relationship with water quality was positive or negative. The non-point source pollution potential of each minor watershed was then scored by summing the rank values of the water quality predictors for that minor watershed. The minor watersheds were mapped by percentile.

Water orientation characteristics tended to show good relationships with several water quality parameters. When totaling the minor watershed scores, the rankings for the water orientation characteristics were doubled. Also, there was evidence that water quality in the Red River Valley ecoregion was related to wind erosion. Wind erosion as a predictor was ranked and scored for this ecoregion, but was not included for the statewide non-point source pollution potential estimates.

Acknowledgements. The data interpretations and mapping procedures were completed by Gary Fandrei and Sylvia McCollor of the Minnesota Pollution Control Agency. Critical reviews were provided by staff of the Minnesota Pollution Control AGency, Department of Natural Resources, Department of Agriculture, the Soil Conservation Service, and the U.S. Environmental Protection Agency Environmental Research Laboratory Corvallis.

THE REGIONAL NATURE OF LAKE WATER QUALITY ACROSS MINNESOTA.
Steven A. Heiskary and C. Bruce Wilson, Minnesota Pollution Control Agency, 520 Lafayette Rd., St. Paul, MN 55155.

The diversity and number of lakes in Minnesota may be better understood by the use of regional characterizations of lake and watershed information. Previous investigators, such as Moyle recognized distinct regional patterns in lake productivity across Minnesota that were generally considered a function of geology, vegetation, hydrology, and landuse. Recent efforts have used the ecoregion approach to define seven regions across Minnesota, four of which contain 98 percent of our lake resources (Figure 1). Typical landuse patterns vary regionally as do lake water quality patterns. Understanding these patterns will assist lake managers developing realistic goals and minimize false expectations.

The objectives of this presentation are to examine regional patterns in the trophic state and morphometry of Minnesota's lakes and to discuss the implications of these findings for lake management applications. Most of the data referred to in this presentation was collected between 1985-1989.

Available data for approximately 1,400 lakes statewide provides sufficient information toe examine general patterns of trophic status and morphometry between the regions. In terms of morphometry the lakes of the Northern Lakes and Forests (NLF) and North Central hardwood Forests (NCHF) are rather similar, which typical surface area ranging from 40-280 ha and maximum depths ranging between 6-17 m. In contrast, the two agricultural ecoregions - Western Corn Belt Plains (WCBP) and Northern Glaciated Plains (NGP) exhibit somewhat larger and shallower basins, typically 60-300 ha in size and 2-6 m in depth.

Analysis of total phosphorus (TP) and Secchi transparency data from this same data base reveals patterns in water quality. The following are median TP and Secchi measurements by ecoregion:

	NLF	NCHF	WCBP	NGP
TP (ppb)	24	60	135	179
Secchi (m)	2.7	1.4	0.5	0.6

Based on these data we note three rather distinct classes or regions, i.e. NLF (forested), NCHF (transition), and the two agriculture dominated regions.

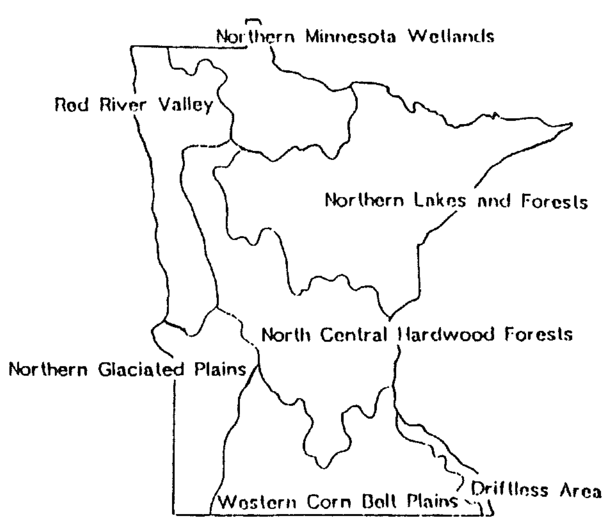
A second database consisting of approximately 90 reference lakes distributed among the four ecoregions has allowed a refinement of this analysis. Regional reference sites (lakes) have watersheds characterized by regionally predominant landscapes that are minimally impacted by nonpoint sources of pollution. There were no known point sources affecting the reference lakes. The reference lakes facilitated the definition of likely ranges of "natural background levels" of lake water quality that were used to help define attainable water quality goals by region.

Data from the reference lakes, in conjunction with several other factors, such as, lake user perceptions, lake uses, lake morphometry, regional phosphorus export values, and watershed characteristics have been used to develop regional phosphorus criteria. These criteria reflect inherent differences between the ecoregions and provide a basis for protecting water quality or as a basis for setting reasonable goals for improving water quality.

The concept that lake and land resources vary regionally has been used for some time in resource management activities in Minnesota. Regional patterns in lake water quality, morphometry, and watershed characteristics have been redefined for Minnesota based on the ecoregion approach. These regional assessments facilitate the definition of reasonable goals expressed in terms of average summer nutrient concentrations, probability of nuisance conditions, and probability of Secchi transparency ranges for lake resource management.

This research was funded by the Minnesota Pollution Control Agency. The authors would like to thank Marvin E. Hora and Curtis J. Sparks for their support of this work. Helpful comments and suggestions were provided over the course of this research by Phil Larsen and Jim Omernik of the U.S. EPA Environmental Research Laboratory at Corvallis, Oregon.

Figure 1. Minnesota's ecoregions.



GIS USE FOR MULTIPLE WATERSHED ANALYSIS OF WATER QUALITY RELATIONSHIPS. Carol A. Johnston, Naomi E. Detenbeck, and Gerald J. Niemi, U.S. EPA, Duluth, MN 55804 and Natural Resources Research Institute, University of Minnesota, Duluth, MN, 55811.

We examined the effect of wetlands and other landscape components on stream water quality in 15 watersheds of the Minneapolis-St. Paul region using Geographic Information System (GIS) and multivariate statistical techniques. The GIS was used to record and measure 33 watershed variables derived from historical aerial photos. These watershed variables were then reduced to eight principal components which explained 86% of the variance. Relationships between stream water quality variables and the three wetland-related principal components were explored through stepwise multiple regression analysis.

Cumulative wetland area, as percent of watershed, had few effects on stream water chemistry at the mouth of the watershed: lower annual concentrations of Pb, Cl, and specific conductance, lower spring and summer NO_3, and higher summer and fall PO_4. Watersheds with abundant *Typha* marshes had higher in-stream levels of TOC and COD. Watersheds with wetlands close to the watershed mouth had better stream water quality than did watersheds with wetlands farther upstream: lower annual concentrations of inorganic suspended solids, fecal coliforms, NO_3, specific conductance, flow-weighted NH_4 and flow-weighted total P. These results demonstrate the importance of wetland position in the drainage basin to ecological function at the landscape scale, which would have been difficult to detect without a GIS. Differences in the relationships derived for time-weighted as compared to flow-weighted averages suggest that wetlands were more effective in removing suspended solids, total phosphorus, and ammonia during high flow periods, but were more effective in removing nitrates during low flow periods.

THE ANOKA SAND PLAIN REGIONAL ASSESSMENT - A PILOT STUDY.

Gary N. Meyer and Kenneth L. Harris, Minnesota Geological Survey, 2642 University Avenue, St. Paul, MN 55114-1057

Due to the urgency of ground-water planning in Minnesota, many agencies and local and regional groups are working to improve our knowledge of Minnesota's hydrogeology. The Minnesota Geological Survey is cooperating with other entities and the consulting community to facilitate transfer of sound technical information in a usable form to decision makers and resource managers. An important effort toward this goal is the Survey's county atlas program. With cost sharing from interested counties, the MGS prepares a series of detailed maps depicting the county's geology and hydrogeology at a scale of 1:100,000. The regional assessment program, planned to incorporate 3 to 5 counties, is intended to give a "head-start" to the county atlases by mapping large areas of the state more quickly, albeit at the smaller scale of 1:200,000. The first regional assessment of four counties in the Anoka sand plain has been funded by the Groundwater Bill of 1989, in a legislative appropriation administered through DNR-Waters.

Anoka, Chisago, Isanti, and Sherburne Counties together encompass the bulk of the Anoka sand plain, an area considered vulnerable to groundwater contamination because of the high permeability of its surficial sediments and the rapid pace of urban expansion of the Twin Cities and St. Cloud metropolitan areas. Emphasis will be on the Quaternary sediment and near-surface ground water. In addition to maps of the surficial geology and the water table, a map depicting ground-water susceptibility to surface contamination will be constructed. All maps will be compiled using the MGS's new Geographic Information System.

About 5500 water wells within the four-county area already have been verified as to location and their logs entered into the MGS computer file. An additional 5000 logs are being added to the file during the regional assessment. Most of the new wells are located in parts of the counties where well control is poor. Soil boring logs from state, county, and municipal sources will also be cataloged. An integral part of the regional assessment involves working with the county staffs to develop proper methods for collecting ground-water data and using the data to evaluate local geologic and ground-water conditions. Once data bases are established at the county level, county staff will be able to add new data and adjust local water- and land-use plans accordingly.

The focus of future regional assessments may vary, depending on the geologic setting and perceived hydrogeologic problems of a particular region. In some areas of the state, additional information derived from drilling and geophysical surveys will be required.

USE OF GIS IN DEVELOPMENT AND IMPLEMENTATION OF BELTRAMI COUNTY'S COMPREHENSIVE LOCAL WATER PLAN. Dale E. Krystosek, Beltrami Soil and Water Conservation District, 403 Fed. Bldg. Bemidji, MN. 56601

Introduction. Geographic Information Systems (GIS) have proven to be a useful tool in preparing and implementing Beltrami County's Comprehensive Local Water Plan. Water Planning in Beltrami County began in November 1987, and was a cooperative effort of the Beltrami Soil and Water Conservation District (SWCD), The Headwaters Regional Development Commission (HRDC), And Bemidji State University (BSU). Representatives from these agencies formed the project staff for the effort. Early in the process, project staff decided that several key sets of data related to water use management should be collected to enhance the value of the water plan. Staff decided that loading the information into the GIS could allow for efficient storage, display, analysis, and manipulation of the data during water plan preparation, and provide a data base to facilitate waterplan implementation.

Land use update. Existing land use information was available from the Land Management Information Center (LMIC) in the MLMIS 40 format. This information had been collected in 1969 at 40 acre resolution, but was considered to be outdated due to rapid land use changes in the Bemidji area in the preceding 20 years. The decision was made to update land use for Beltrami and Clearwater County by refining the 1969 40 acre data into 2.5 acre resolution in 1988. The EPPL7 GIS software package, developed by the Minnesota State Planning Agency, was used for the update. Reasons for selecting EPPL7 included low cost, compatibility with existing land use data, and readily available local expertise at the BSU Geography Department. Roles of the cooperating agencies in the land use update included the SWCD completing photo interpretation and coding 15 different land use classes onto township base maps produced by LMIC. The HRDC coded the location of rural residencies in the 11 townships surrounding Bemidji, and BSU Geography students edited the land use changes on the EPPL7 program. Beltrami SWCD staff utilized black and white aerial photos, color aerial slides, USGS topographic maps, and the local staff's knowledge of the county as tools in the update. Approximately 2,500 hours of staff time were put into the land use update of Beltrami County, 1.6 million acres in size. Problems encountered in the update included an excessive time commitment, and the grid cell, or raster, based system posed problems in accurately representing small or meandered features such as wetlands, streams, and field boundaries. Point data such as abandoned wells or underground storage tanks were also difficult to represent.

Collection of other data layers. Additional data related to water resource management including locations of dumpsites, feedlots, underground storage tanks, and wild rice beds were entered into the GIS. Analytical capabilities of the GIS were used in a limited way to analyze the spatial distribution of certain land use classes in relation to location of lakes and streams. Soil survey information for part of Beltrami County had been computerized on the Soil Survey Information System (SSIS) program developed by the University of Minnesota Department of Soil Science. This GIS was very useful for mapping soils within the county where highly erodible soils posed a potential threat for sedimentation loading into surface waters, and as a tool in groundwater sensitivity mapping. The SSIS files were also loaded into the EPPL7 program allowing for overlaying of data layers. Soil series were separated into classes based on permeability and then overlaid with land use and potential non-point pollution sources to produce simple groundwater hazard potential maps. These maps and other GIS outputs were used as educational tools in water planning task force meetings.

Use of GIS in water plan implementation. GIS are also proving to be very useful tools in implementing the strategies of the Beltrami County Comprehensive Local Water Plan. The systems are being used to map watershed and sub-unit boundaries, stream and lake locations, and potential non-point pollution problem areas for the Lake Bemidji Watershed Study, a Clean Water Partnership Project. Groundwater data from the Bemidji-Bagley Groundwater Study, abandoned well inventory data, lake watershed information, and other data layers are also being entered into a GIS with the assistance of the University of Minnesota Remote Sensing Laboratory. A comprehensive, working GIS is expected to be an effective tool in managing multiple data sets for the various strategies of the local water plan.

Summary. The use of Geographic Information Systems proved to be a very useful tool in developing and implementing Beltrami County's Local Water Plan. The GIS programs being used provided an effective and efficient means of storing, mapping, displaying, manipulating, and overlaying water resource data. Data collection activities have proven to be labor intensive and costly, but the benefits afforded by a working GIS have far out-weighed the costs.

GROUND WATER PLANNING IN HENNEPIN COUNTY, MINNESOTA. James Piegat, Hennepin Conservation District, 12450 Wayzata Boulevard, Suite 205, Minnetonka, MN 55343.

The Hennepin Conservation District (HCD) is currently preparing a county ground water plan for Hennepin County. Initial planning and subsequent management will rely heavily on computers and a geographical information system (GIS) because of the large amount of data involved. The county currently has a population of one million persons who live on 350,000 parcels of land. There are water well logs for nearly 20,000 of an estimated 140,000 to 170,000 wells in the county. The Minnesota Pollution Control Agency listing of underground storage tanks in the county is 352 pages long.

Compatibility with systems used by principal clients must be considered when selecting a GIS . Agencies are less likely to use outside products that require considerable translation to their systems. UltiMap was selected by HCD because it is used by Hennepin County and several of the larger cities within the county.

A map is useless if it does not include a spatial guide to familiar or easily identified landmarks. HCD is using the parcel map created and maintained by the Hennepin County Surveyor as its GIS base map. This map includes Public Land Survey lines, water lines, parcel lines, and roadways. Issues that must be considered when using a base map created by others include map projection, density of information, and the nature of particular lines and points. For example, a line that partially delineates a parcel abutting a water body is not the same as the line for the ordinary high water mark of that water body.

The need for human interpretation as a major part of computer modeling, including GIS, cannot be overemphasized. Structure and isopach maps of the county's principal aquifers are needed for ground-water models. GIS can manage the data in WELLOG and on geologic and topographic maps of the bedrock, but preparation of the maps will require considerable geologic interpretation that no computer can perform.

HCD will use data bases created and maintained by state agencies. As an example, the MGS Water Well Log Data Base (WELLOG) can be added to the GIS without digitizing the location of each of the 10,000 to 20,000 wells in the data base. This task includes converting the Universal Transverse Mercator (UTM) coordinates of each well to State Plane grid coordinates.

Ground-water sensitivity is based on the nature of the geologic materials through which water and contaminants flow. The vertical and lateral variation of glacial material is impossible to portray on standard, two-dimensional maps. Cross-sections are of little value because the information they show cannot be extrapolated for any distance away from the line of section. One solution to this problem is a "stack" map. The map units of a stack map indicate all of the geologic layers, or the "stack", found within a particular area. GIS can speed the interpretation required for preparing a stack map.

Ground water moves through a relatively small part of an aquifer to a well when the well is pumped. The premise of a wellhead protection program is that a well will not become contaminated if contaminants are not released above that part of the aquifer that feeds the well.

Wellhead protection areas (WHPA) can be delineated by a variety of methods. Analytical WHPA's will be determined for each public water supply well in the county. GIS will greatly speed the process by sorting the data that an analytical method requires to draw WHPA's. GIS can then identify land uses that generate, store, use, or dispose potential contaminants within each WHPA.

Managing ground water requires information concerning the distribution and magnitude of existing and future water uses. GIS can manage water-use data according to capacity, pumpage reports, aquifer, use, and time period. Ground-water use and water-level data from observation wells can provide understanding of the effects of climate on ground water supplies.