Ground Water Sustainability:
A White Paper

Ground Water: A Critical Component of the Nation's Water Resources

Ground water is a critical component of the nation's water resources. Globally, ground water resources dwarf surface water supplies. Approximately 25 percent of the earth's total fresh water supply is stored as ground water, while less than 1% is stored in surface water resources, such as rivers, lakes, and soil moisture. The rest of the freshwater supply is locked away in polar ice and glaciers (Alley 1999a). Because ground water is hidden, the resource is often forgotten or misunderstood. In fact, until 1984, courts in Ohio held ground water movement "secret" and "occult" (Cline 1984).

Ground water resources dwarf surface water supplies.

Ground water is, in fact, vital to public health, the environment, and the economy. Approximately 75% of community water systems rely on ground water (U.S. Environmental Protection Agency 2002a). Nearly all of rural America, as well as large metropolitan areas, use ground water supplied water systems. In many parts of the country, surface water supplies are inadequate or unavailable, and ground water is the only practical source of water supply. Ground water feeds streams and rivers, especially during periods of drought or low flow. The agricultural industry uses ground water for irrigation. The percentage of total irrigation withdrawals from ground water increased from 23 percent in 1950 to 42 percent in 2000 (Hutson 2004).

The nation's aquifers have been estimated to receive about one trillion gallons of recharge each day (Nace 1960) but the recharge rates vary greatly both from region-to-region as well as within regions. Even with this vast resource beneath our feet, many parts of the country are experiencing regional and local declines in water levels in aquifers (more than 800 feet in some areas), salt water intrusion along the coastline, land subsidence (Leake 1997), declining water quality due to over pumping, contamination from human activities, and reduced flows to streams.

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Twenty-six of 28 state agencies responding to a National Ground Water Association (NGWA) survey perceive current or anticipate ground water supply shortages at a statewide or local level in the next 20 years. A separate NGWA survey of public and private sector ground water professionals adds to the state agency assessment. Ground water professionals in 41 of 43 states believe ground water shortages currently exist or will exist in the next 20 years in their states or localized areas of their states (NGWA 2003a; 2003b).

national ground water association®
Phone/ Toll-free 800 551.7379/ 614 898.7791 **Fax/** 614 898.7786
Web/ www.ngwa.org and www.wellowner.org
Address/ 601 Dempsey Road/ Westerville, Ohio 43081-8978 U.S.A.

To protect our citizens, our economy, and the environment, it is important that we understand the factors that contribute to local, regional, or statewide ground water shortages; the strategies that can be implemented to promote a sustainable ground water supply; and what resources or tools are needed to implement these strategies successfully.

Factors that Contribute to Ground Water Shortages

Population Growth and Distribution Patterns

High population growth rates in arid and semi-arid areas and the urbanization of America have a direct impact on the balance of supply and demand on our nation's ground water resources. The largest census-to-census growth took place from 1990 to 2000, which accounted for an increase of 32.7 million people. The arid Western states experienced the fastest growth rate in the nation at 19.7% during this period, forcing many to struggle to find new sources of water (Perry 2001). The continued concentration of population within or adjacent to metropolitan areas stresses localized ground water sources, even in so-called water rich areas. The legal and political mechanisms of allocating water are struggling to adapt to new priorities and rising demands.

The Chicago-Milwaukee metropolitan area: a case study of population growth and its effect on water supplies.

The area has a long history of pumping ground water from a regional confined bedrock aquifer dating back to at least 1864. Over many decades, ground water pumping increased to supply industries and municipal water supply. By 1980, pumpage from the aquifer had increased to several times the estimated sustainable yield of the aquifer, based on Illinois State Water Survey estimates (Burch 2002). Water levels decreased by more than 800 feet from predevelopment conditions in the Chicago area and by almost 500 feet in the Milwaukee area. Several wells began experiencing rising levels of salinity as water was drawn from deeper portions of the aquifer. In response to the depletion of the aquifer, several municipalities switched to surface water from Lake Michigan as a source of supply in the 1980s. The aquifer recovered by more than 250 feet in places as the pumping rate was decreased. However, the use of Lake Michigan water constitutes a regulated diversion out of the Great Lakes Basin due to the presence of the subcontinental divide within a few miles of the Lake Michigan shoreline. The region has reached the maximum limit of their diversion and new water demand in the outlying suburbs is largely coming from new wells in the same confined aquifer. As a result, water levels have started to decline in some areas around the edges of the metropolitan Chicago area. Water levels continue to decline by between 5 and 10 feet a year in the Milwaukee area where communities on the west side of the subcontinental divide have been unable to get a diversion of Lake Michigan water. Currently, neither area has a plan in place to meet existing and future demands in a sustainable manner, although discussions are currently taking place.

Contamination or the Presumption of Contamination

While U.S. ground water quality generally remains good, contamination has affected the resource. Recent methyl tertiary-butyl ether (MTBE) and perchlorate contamination incidents, for example, affect localized ground water supply. In California, perchlorate has been detected in more than 300 public supply sources and an equally large number of private homeowner wells (California Department of Health Services 2004). Agricultural chemicals impact ground water quality in many parts of the country. Contamination of nitrate from fertilizers and animal waste is common. A recent sampling program in Wisconsin found traces of pesticides or their breakdown products in 38% of samples from wells in the State (Krohelski 2004). In many cases, the lack of reliable information on the extent and quality of ground water resources is a significant factor hampering efforts to respond to emerging problems.

Naturally occurring constituents, such as arsenic, radium, or chloride, render some ground water unusable for drinking or other purposes without treatment. In portions of the arid Southwest, Northeast, and the temperate Midwest, arsenic naturally occurs in ground water above the recently lowered drinking water standard. Approximately one-third of Arizona water systems exceed the new 10 ppb standard for arsenic (Arizona Department of Environmental Quality 2003). In some cases the level of arsenic is compounded by decreasing water levels. For example, in central Wisconsin, declining water levels have been linked to increased levels of arsenic due to oxidation of freshly exposed sulfide mineral source material (Riewe 2000). More than 4000 public water systems nationwide will have to pay for new treatment systems or find new water sources as a result of the arsenic rule (U.S. Environmental Protection Agency 2001). The vast majority of these systems are small systems that serve few users and have limited financial resources.

Our ability to detect constituents in water at lower and lower concentrations also presents new challenges. Detection technology is often outpacing our understanding of what the findings in *parts per billion* or *trillion* mean to the suitability and use of ground water for specific purposes. Contaminants such as N-nitrosodimethylamine (NDMA), pesticide breakdown products, and pharmaceutical agents (drugs) are being found in ground water at trace levels. The consequences for human health and the environment are still unknown. Also critical in this arena is the continued support of research and development of remediation technologies. The remediation of one contaminant can often be applied to other pollutants. Understanding public health concerns and the realities and support of remediation technologies must be considered simultaneously when making public policy decisions.

In North Carolina and elsewhere, shallow aquifers may be avoided because of a presumption of contamination

In North Carolina and elsewhere, shallow aquifers may be avoided because of a presumption of contamination. This presumption may be based on unease rather than scientifically valid information about ground water quality in the specific area. These aquifers typically receive more recharge than deeper aquifers and in many cases offer a sustainable alternative to over-pumped confined aquifers.

The fear of contamination is often more restrictive on ground water availability than the actual contamination problems may warrant. “Surface water systems tend to be more vulnerable than ground water systems for most contaminants," according to U.S. EPA (U.S. EPA 1999). With better monitoring of ground water quality, as well as with the use of continuously improving water treatment technologies, these aquifers could become an economic and reliable source of water.

Increasing Efforts to Protect and Enhance In-Stream Flow and Aquatic Ecosystems

Ground water's contribution to stream flow varies. For small and medium sized streams, estimates are that between 40 and 50 percent is from ground water seepage (Alley 1999a). Surface water also provides a source of ground water recharge. The potential for impacts to in-stream flows and aquatic ecosystems may, in some cases, limit the amount of ground water available for extraction. Conversely, surface water withdrawals or the lining of irrigation channels may adversely impact ground water replenishment. The interaction between surface water and ground water is complex and site-specific. Comprehensive water management requires a thorough understanding of the local ground water system to be effective.

There is generally no "extra" water in an aquifer. Water captured by a pumping well will result in some combination of a loss in discharge to surface water at some other location, an increase in recharge from surface water, or a loss of storage in the aquifer. Ground water and surface water are a single resource in constant flux. Because it is impossible to use a natural resource without having some effect on it, zero impact is neither a possible nor a desirable goal. However, by understanding the linkages between ground water and other water-dependent natural resources, we can make informed decisions and sustainable compromises.

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Natural ground water resource and recharge variability

It is estimated that the United States uses only about 8% of the fresh ground water that is being recharged daily to its aquifers (Alley 1999b). The ability to capture more of the available recharge is limited by the frequent disparity between the availability of ground water and the centers of concentrated demand, the lack of regional planning to facilitate water transfers, and the needs of other users and the environment on ground water supplies.

Ground water resources and recharge rates vary locally and regionally across the United States and within individual states. Different geologic formations retain water differently. Sand and gravel formations have more pore space to store and release ground water. Precipitation will generally run off in areas overlain with tight soils or hard rock, such as shale or granite, and in developed areas where pavement prevents the infiltration that occurred before development. In many aquifers, ground water is found in fractures within or between the rock layers rather than in uniformly distributed pores. These fracturedominated aquifers have low capacity to store ground water and an uneven distribution of permeable zones where wells can be completed.

The underlying geology can result in ground water poor regions even in areas of plentiful rainfall. Southeast Ohio is an example of a ground water poor area, even though precipitation averages more than 39 inches annually (National Oceanic and Atmospheric Administration 2000). In some areas of the country, ground water currently being withdrawn entered the aquifer as recharge thousands of years ago during a wetter climate that no longer exists. Thus, the water consumed is not being replaced because the area now receives minimal natural replenishment through rainfall. An example is the U.S. Southwest, where climatic conditions millennia ago varied greatly from the current arid conditions. Much of the water being produced may be a relic of the last ice age and is not being replaced under the current climatic conditions.

Current water infrastructure system design

Today’s drinking water infrastructure often involves centralized, large-scale ground water withdrawals. In regional systems, the extracted ground water may be piped miles away from the original withdrawal point. Centralized wastewater systems further compound the problem by collecting the used ground water, treating it, and releasing the water into a stream. The receiving stream may be in a different hydrologic basin from where the ground water would have naturally discharged, creating a diversion of water from one basin to another. Rather than renewing the original ground water supply, it flows out of the system. Even in some rural areas and small communities, we are moving away from individual or small drinking water and wastewater systems that largely maintained the water within the local ground water system.

We must develop and design our manmade water infrastructure systems with greater consideration of the systems’ impact on the natural water system.

As a nation, we must begin to develop and design our manmade water infrastructure systems with greater consideration of the systems’ impact on the natural water system. With the nation facing water supply shortages, significant water infrastructure replacement costs, and water system security concerns, now is the time to scrutinize existing paradigms for drinking water and wastewater delivery and identify whether changes may be beneficial (see generally Congressional Budget Office 2002, U.S. Environmental Protection Agency 2002b, U.S. Environmental Protection Agency 2003).

Methods Available to Promote a Sustainable Ground Water Supply

There is no universally accepted scientific definition of ground water sustainability that is applicable in all situations. For purposes of this paper, ground water sustainability is the development and use of ground water to meet both current and future beneficial purposes without causing unacceptable consequences. Ground water sustainability involves minimizing net losses from the hydrologic reservoir (resource renewability), management of ground water as an integrated part of the hydrologic cycle, development of manmade infrastructure based on an understanding of the natural hydrologic system, wise and efficient water use, and fair allocation and monitoring of water for human as well as environmental and ecological needs. Defining ground water sustainability for a particular situation is a policy question that requires not only incorporating scientific information and principles, but also legal, social, environmental, and economic considerations.

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The following summarizes some potential methods available to help achieve ground water sustainability. Case examples from around the country are provided.

Use Sources of Water Other Than Local Ground Water

Using sources other than local ground water warrants switching or supplementing local ground water with available surface water supplies. In some areas, this may be a viable option. In the 1980s, a seven county area around the City of Chicago abandoned hundreds of municipal and industrial wells withdrawing from an overexploited aquifer and switched to a centralized water system using water from Lake Michigan. The allowable diversion of Lake Michigan water is now fully allocated so no additional water can be withdrawn by Illinois.

In other locations, surface water may also be fully allocated or unavailable. In these areas, additional alternate sources of supply are being investigated or will be investigated in the future. Possible alternative sources include treating brackish ground water (ground water with a salt content over 2000 mg/l), desalination of seawater, or treating currently contaminated ground water for reuse.

The Metropolitan Water District of Southern California, the primary wholesale provider of imported water for the southern California regions, has a portfolio of diversified supplies. They include water conservation, water recycling, desalination, Colorado River deliveries, state water project deliveries, water transfers, storage in ground water basins and surface reservoirs, and drought contingencies. Arizona is in preliminary discussions about a regional brackish water desalination plant. Both the Phoenix and Tucson areas are participating in the Central Arizona Salinity Study. While Arizona does not face an immediate need to treat and use saline ground water, they are preparing for the possibility if growth persists (Water Resources Research Center 2004).

Change Rates or Spatial Patterns of Ground Water Pumpage

As noted, withdrawing large amounts of ground water from centralized locations may overstress the system. Centralized water withdrawals, especially from confined aquifers where low-permeability geologic layers between the land surface and aquifer restrict rainwater from reaching the aquifer, can cause “mining” of the aquifer – using more water than is naturally replenished. Land subsidence can also result if the confining geologic layer and aquifer materials compact when the water is pumped out but not replaced. Decreasing pumping rates may help. Additionally, increasing the number and spatial distribution of the withdrawal points may allow the same quantity of ground water to be extracted with a minimization of the adverse effects.

For example, the city of Dunedin, Florida, uses an automated pumping schedule to minimize the negative impacts of over-pumping an area of their aquifer in order to avoid the intrusion of brackish water into its wells. Withdrawing ground water, much like donating blood, can be sustained if it is taken at measured levels, but can be detrimental if too much is taken too quickly.

Increase Recharge to the Ground Water System

One method to increase ground water recharge to aquifers is through well injection systems. The water used for injection may come from treated wastewater or other return flows. The water is treated to meet necessary regulatory standards and then injected below ground for storage and future use. In areas of the United States where ground water resources have been strained by urban sprawl or agricultural uses, such as central Florida, the use of Rapid Infiltration Basins (RIBS) at treatment facilities, such as ConservII, is becoming a standard practice for inducing the infiltration of treated wastewater into aquifers.

Other parts of the country use infiltration basins or recharge wells to increase the level of recharge to the system by trapping storm water that would normally run off to surface water. This approach has the added benefit of reversing some of the increased runoff that results from urbanization and reduces storm water flooding. A recent survey of NGWA members indicated that the majority believes that more research is needed prior to the widespread adoption of aquifer storage and recovery wells using treated wastewater as a water source, but that it is a solution worth exploring (NGWA 2003a).

Use Aquifers as Reservoirs

Ground water may be withdrawn from underground storage and used during dry periods. This will result in a short-term reduction in ground water levels. If this short term reduction is balanced in the long term with replenishment, ground water can be used much like an above-ground reservoir to store water for use when other sources are in short supply. The Arizona Water Bank is an example of this strategy. Nevada and California store excess Colorado River water underground in Arizona. During drought periods, Nevada and California divert surface water flow from the Colorado River while Arizona recovers the underground stored water for its uses.

On a local scale, some water utilities around the country use aquifer storage and recovery (ASR) wells to store water in an aquifer from an alternate source when excess water is seasonably available. Examples of this could be surface water taken during wet times of the year or shallow aquifers that can be pumped more heavily during certain months or in years of heavy recharge. The excess water is injected into a deeper aquifer and stored until it is needed. The water is then pumped out of the storage aquifer, typically using the same well through which it was injected.

Developing a Ground Water Sustainability Strategy

Determining which method or combination of methods to employ in a particular situation to promote a sustainable ground water supply generally should:

- Be made at a local level, whether that is a state, some government subunit, or an aquifer or ground water basin level. Local decision making provides the necessary flexibility to tailor the strategies to the specific situation. Ground water resource and climatic variability makes a one-size-fits-all approach unworkable. Local ground water management plans can incorporate site-specific information and input from all potentially affected parties. Implementation tools, such as land use planning or conservation measures, are also available at the local level.

- Provide for meaningful community involvement. Ground water sustainability affects the country on an individual, local, state, and national scale. Ground water sustainability requires the identification of current and future beneficial uses and a determination as to what consequences are acceptable. This determination is a value judgment requiring a balancing of many factors for a given situation. Factors that contribute to the availability of water resources discussed in this paper vary from location to location due to differences in need, availability, climate, geology, hydrogeology, and solution choices.

- Respect state water laws. State water laws must be viewed as a current statement of community values and judgment.

- Comply with federal environmental and public health goals. Compliance with these goals is required to provide consistent levels of environmental quality and public health protection and should work to prevent local management districts from unexpected and unplanned costs.

- Be based on sound scientific data and research. Needed scientific information may include the hydraulic properties of aquifers, ground water levels, accurate ground water use and consumptive use data, aquifer water quality, ground water recharge rates, and aquifer maps.

Resources or Tools Needed to Implement Strategies

While states are gathering the necessary data to inform decision making, no state has met its data collection goals. In fact, only two of the 28 states responding to an NGWA survey are very confident that they know the potential yield from all of the state's major aquifers. We lack the fundamental data necessary to adequately understand the nation's ground water resources and make informed decisions regarding its use and management (NGWA 2003a; 2003b).

The federal government is currently playing and must continue to play a vital role as well. Although actual ground water management decision making is most effective when taking into account site-specific considerations, federal funding of cooperative data collection and aquifer mapping leverages the expertise and resources of the federal government with partners around the country.

NGWA members identified increased federal funding for cooperative ground water quantity data collection as the most useful action the federal government can take. Members also identified federal support of cooperative data collection of ground water quality, aquifer mapping, and pertinent scientific research as important (NGWA 2003a; 2003b). Within each area, examples of possible specific activities are provided for consideration and further discussion.

Data Gaps

- Establish a collaborative framework among federal, state, local, and non-governmental entities to address data gaps on ground water resources. Collecting ground water data is costly, given its location and variability. While specific data gaps and priorities may vary around the country, collaboration will help maximize everyone's data-gathering efforts.

- Increase federal funding for cooperative ground water quantity data collection. Ground water professionals identified the need for additional federal funding for cooperative ground water quantity data collection as the most useful federal action. The data would be used to fill information gaps and will assist states in developing and implementing overall ground water management goals. The federal government should develop a cooperative program with the states and other interested parties so goals meet not only national but also state and local needs as well. First steps include assessing available data, identifying questions that need to be addressed, and identifying the appropriate role of federal agencies. A potential model to follow is the National Cooperative Geologic Mapping Program, which includes a federal, state, and educational component.

- Provide federal support for aquifer mapping. Funding for geologic mapping is provided to state geological surveys through the USGS

STATEMAP program, the state component of the National Cooperative Geologic Mapping Program. The STATEMAP program utilizes state staff knowledgeable in the local geology who maintain the data upon which much of the mapping is based. The states, not the federal government, also select the areas of the state that are in most need of mapping data. The program provides a comprehensive understanding of the geology at/near land surface, in which ground water is commonly a major consideration. Limitations of the program are that it requires 1:1 matching of state funds; the mapping is required to be completed within one year; derivative maps such as fracture trends are not considered for funding; and maps do not necessarily focus on delineating subsurface aquifers.

Another federal-state cooperative program involves the USGS and the state surveys from Illinois, Indiana, Michigan, and Ohio. This partnership, known as the Central Great Lakes Geologic Mapping Coalition, is conducting three-dimensional geologic mapping mainly at 1:24,000-scale, specifically targeting the delineation of glacial aquifers. Limited funding has allowed only pilot study areas to be mapped during the last three years. However, the states and USGS have contributed considerable federal and state funds toward the effort. If additional funds are not forthcoming, it will take about 170 years to complete this mapping in high-priority areas of the four states. Although underfunded, the Coalition serves as an excellent example of how a federal-state partnership can address the specific needs of a region that is united by common ground water issues.

- Establish a national clearinghouse to identify sources of ground water data and links to those sources. These data should be disseminated widely to the public using several formats. These formats should include maps and reports showing interpreted data as well as Internet-based access to archived data and real time data collection. These data should be available from links on already existing National Spatial Data Infrastructure (NSDI) sites to make the information easier to find and assure that the proper documentation of these data is maintained.

<u>Research Priority Areas</u>

The following research areas have been identified by our ground water professionals as top priorities in the area of developing long-term ground water sustainability:

- Research on water reuse and conservation.
- Research on alternative treatment systems.
- Research on the development of brackish ground water supplies.
- Development of models and data standards that can bring together scientific data and inform local policy decision makers.

- Research on aquifer storage and recovery or artificial recharge.
- Research on emerging contaminants and the development of remediation technologies that can be used to address new and current pollutants.

Education and Collaboration among Federal, State, and Local Decision Makers

It is important for collaborative efforts among federal, state, local, and non-governmental entities and water professionals to educate decision makers, professionals, and the general public on topics such as:

- What ground water data are being collected and what data are needed.
- How to utilize ground water data to make sound decisions.
- What current research projects and technologies are being developed, and how to incorporate these developments into ground water management decision making.
- What long-term effects does water supply infrastructure design have on the sustainability of the natural ground water system, and how do we design systems that take those impacts into consideration.
- What constitutes effective ground water conservation measures and how to incorporate these initiatives on a state and local level.

The National Ground Water Association is a not-for-profit professional society and trade association for the ground water industry. Our 15,000 members from all 50 states include some of the country's leading public and private sector ground water scientists, engineers, water well contractors, manufacturers, and suppliers of ground water related products and services.

For additional information contact Washington lobbyist, Cartier Esham, at Dutko Worldwide (202/484-4884; cartier.esham@dutkoworldwide.com) or NGWA Government Affairs Director Christine Reimer at 800/551-7379, ext. 560, creimer@ngwa.org.

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