GROUNDWATERSHED STATUS REPORT
PREPARED FOR FRIENDS OF LAKE WINGRA

PREPARED BY MARIBETH KNIFFIN
SUSTAINABILITY LEADERSHIP PROGRAM
EDGEWOOD COLLEGE

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Abstract

This Groundwater Status Report is a summary of existing research, personal interviews and policies with respect to spring and groundwater flow beneath the Lake Wingra watershed. The report begins by briefly describing the springs in the Lake Wingra watershed and how storm sewer runoff has affected their flow rates. The report summarizes the hydrology, groundwater storage and groundwater recharge of the Lake Wingra Watershed and the aquifers beneath it. Looking at all aspects of human interactions with water resources, the report then discusses water consumption and disposal, shallow and deep aquifer connections and a few key groundwater policies established in the State of Wisconsin and City of Madison. At the end of select sections, there are "Topics Recommended for Further Exploration", which are intended to help identify future areas of opportunity for the Friends of Lake Wingra and other readers.

Acknowledgements

I was fortunate to have Jim Lorman and Kathryne Auerback as co-directors of the Sustainability Leadership Program. I owe special thanks to Jim, my principal advisor, for the opportunity to work alongside the Wingra Watershed Management Plan for my capstone project. His active involvement in the community and perspective provided me with excellent learning opportunities. I also thank Kathryne for offering advice and direction throughout the project.

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Several other individuals influenced the results of this report including Genesis Steinhorst, Steve Gaffield, Rob Montgomery, and Beth Churchill. I thank those who I interviewed and whose research and figures influenced the report: Ken Bradbury, Steve Glass, Ken Potter, John Reimer, Brynn Bemis, David Liebl, Chin Wu, and Sue Swanson. Finally, I appreciate all the unnamed individuals who participated in the many meetings that I attended.

1 - Introduction

Water, by its nature, connects all of life and the decisions that we make. Water dictates where and how we construct our societies. By examining a water body, we can determine the values and priorities of those who live in its vicinity. As eloquently put by Luna Leopold, "the health of our waters is the principal measure of how we live on the land."

Despite the numerous studies that have been conducted in the Lake Wingra watershed, the watershed suffers from issues related to urban development including, but not limited to, poor water quality, introduction of invasive species, algal blooms and loss of spring flow. The current state of the water and threat of compromised quality and abundance of water in the future is a social justice, economic and environmental issue. Creating a healthier and resilient watershed will require not only key information from technical research, but a shift in the basic values and practices of the community as well. Identifying the key motivators of change and how to influence these motivators will be critical for success. Ideally, technical research can help identify priorities and leveraging points that inform the change agents who can carry out project implementation.

The recent collaboration between the City of Madison Engineering, Friends of Lake Wingra (FOLW) and other community experts offers a unique opportunity to put this scenario into practice. By the fall of 2011, the City of Madison Engineering will have hired a consultant to manage the "Wingra Watershed Management Plan" for the next one to three years. For this complex coordination project to function, according to seasoned eco-village dwellers Malcolm Hollick and Christine Connelly, what is most important is not the technologies adopted, but "the beliefs and values on which [the project] is based and the relationships which bind members and enable them to work together and resolve their differences." Adhering to the values of service, personal growth, personal integrity, respect for others, direct communication, co-operation, resolution and commitment can help make the Wingra Watershed Management Plan a national model for water resources management.

This *Groundwater Status Report* is an extension of the *Lake Wingra: A Vision for the Future* document developed by the FOLW. In the vision document, the FOLW identify four goals: 1) clear, clean water; 2) restored spring flow; 3) abundant native plants and animals, and 4) stewardship and enjoyment. This report focuses on the second goal, restored spring flow, and was written in partial fulfillment of the Edgewood College Sustainability Leadership Program's capstone requirements. The purpose of this report is to support the goals of the Wingra Watershed Management planning process by compiling pre-existing knowledge about groundwater flow beneath the Lake Wingra Watershed for the FOLW via reviewing research articles and conducting interviews with professionals in the community. This knowledge base can help determine what tools and areas of research are still needed in order to implement and monitor a plan to manage groundwater flow beneath and restore spring flow into Lake Wingra.

2 - Spring Flow & Storm Sewer Runoff

> *A spring is the result of an aquifer being filled to the point that the water overflows onto the land surface.*
> *-United States Geologic Survey*

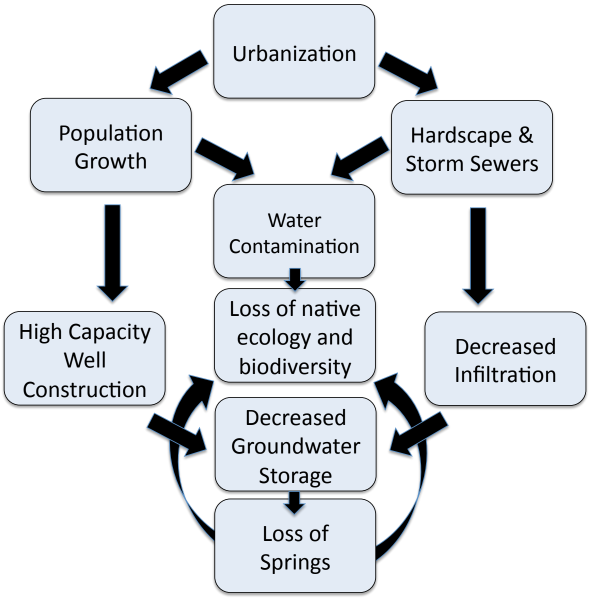
According to Wayland Noland's 1951 report called *Hydrography, Fish and Turtle Population of Lake Wingra*, over 20 springs that formerly flowed into Lake Wingra cease to exist.

Table 1: Lost Springs

Name (# of springs)	Former Location
Reynolds Spring (1)	Outlet at edge of the marsh on the north side
Marsh Springs (5)	Marsh, what is now Vilas Park.
Edgewood Bay Spring (1)	Marsh, what is now Edgewood Bay
Big Fish Spring (1)	Southwest of Edgewood Point
Edgewood Big Spring	Near large willow trees, Edgewood property
East Edgewood Spring (1)	Edgewood property
West Edgewood Springs (4)	Edgewood western shore
Chase Springs (8)	Private property - Woodrow Street & Conklin Park
White Rock/Willow Spring (1)	Monroe Street

Many of these springs have been eliminated by decreased infiltration due to impervious surfaces and groundwater pumping in the Madison urban environment and have been replaced by storm sewer run off (Noland, 1951). Storm sewers direct contaminants (i.e. fertilizers, pesticides insecticides, herbicides, pet waste) from streets and lawns directly into the lake via stormwater runoff (Water Resources Management Report (WRM), 1999).

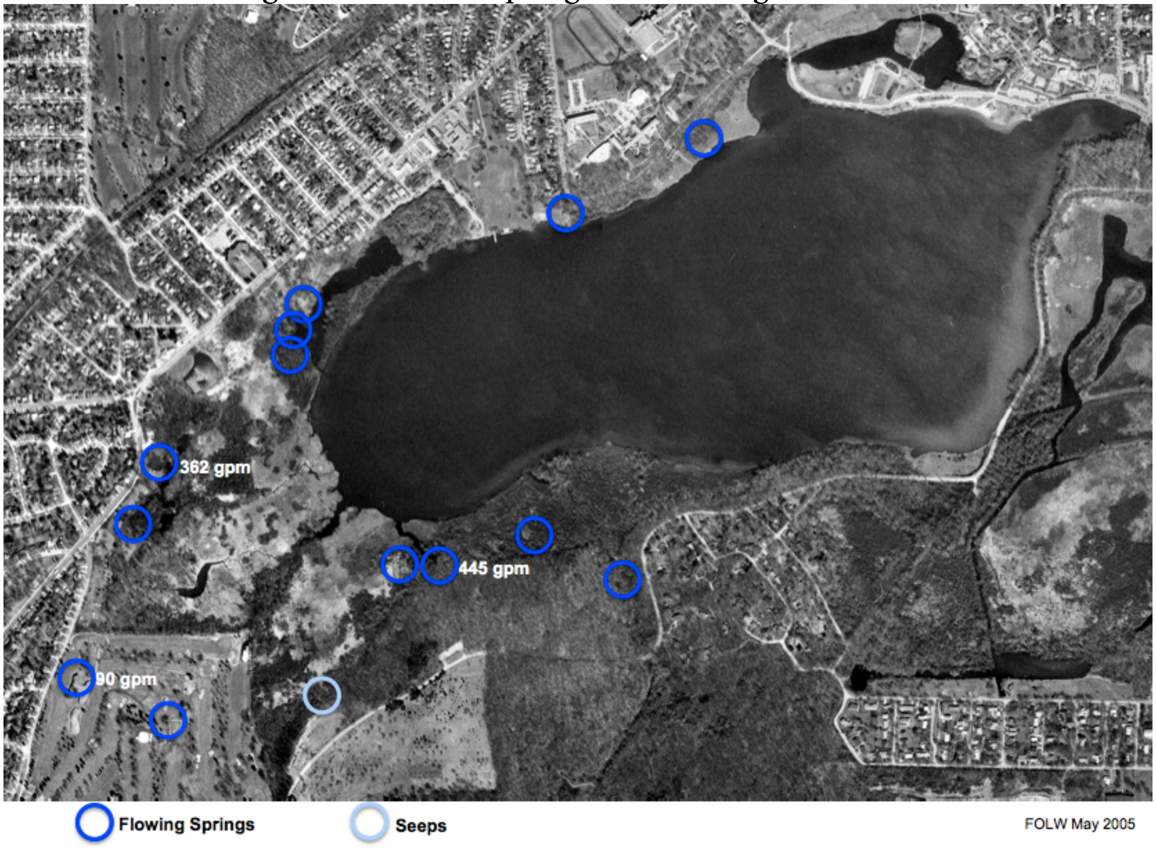
Figure I: Factors Affecting Spring Flow



The nature of the water entering the lake as runoff or piped flow also differs from spring water in terms of regularity and quantity. Rather than slowly percolating in the ground and entering as spring flow, the impervious surfaces lead to more frequent and sever flooding during wet periods. During dry years, the reduced amount of groundwater has caused a loss of springs in Lake Wingra (Lathrop et al., 2006). At times, water levels are too low for and aquatic life needs (Lathrop et al., 2006).

Presently, there are eight identified springs that directly feed Lake Wingra and at least five other springs are located in the Lake Wingra watershed (Glass, personal interview). Six of the springs are located in the UW-Arboretum.

Figure 2: Present Springs in the Wingra Watershed



Ongoing spring monitoring efforts are necessary for quantitatively comparing current flow rates with historical discharge to better understand the impacts of urban impervious surfaces and groundwater pumping on the aquifer and spring flow. Monitoring spring flow and establishing a baseline is also critical in determining the success of infiltration efforts. Madison Gas & Electric (MG&E) conducted one such recharge project at the Odana ponds. In tandem with the construction of the West Campus Cogeneration Facility, MG&E sought to infiltrate filtered surface water into the groundwater to enhance recharge to the groundwater system that discharges to the Yahara River (Montgomery Associates, 2005). According to the groundwater modeling conducted by Montgomery Associates, the Odana Pond project should increase spring flow in Big Spring, one of the springs in the Arboretum (Glass, personal interview).

To determine spring loss and natural spring flow variation, throughout the last several years the Arboretum Restoration Ecology Planner, Steve Glass, started monitoring the flow rates of five predominant springs in the Lake Wingra watershed: White Clay Spring, Dancing Sands Spring, Big Spring, Council Spring, and Nakoma Spring. Though he is still working on the details of his methods, his goal is to collect data four times a year, ideally on the same day, over a period of at least five years to determine a baseline. He currently uses a pygmy meter to measure flow rates. Mr. Glass's data has not yet shown an increase in flow at Big Spring (Glass, personal interview).

Besides Mr. Glass, several University of Wisconsin-Madison students have conducted short=term studies that collected spring flow data and/or spring water quality measurements (i.e. Nick Ballering, Brynn Bemis, David Gildner, Evan Murdock, Linda Severson and Chapin Storrar).

In the spring of 2011, the chloride concentrations of the surface water being infiltrated into the groundwater at the Odana Ponds Project reached levels of concern. At this time, Montgomery Associates, MG&E and FOLW met to discuss potential solutions. Recommendations from this meeting are included in the "topics recommended for further exploration" below. Continuing to monitor the water quality of the infiltrated water as well of the spring flow water will be important for maintaining clean drinking water and understanding the hydrogeology of the area.

Since the development of impervious surfaces has caused storm water to replace the prevalence of groundwater fed springs, using storm water utility funds to increase the surface water infiltration may be an appropriate allocation of funds. This was one of the major recommendations of the 1999 UW-Madison Water Resources Management Report. The report also suggested creating a storm water utility advisory board to create efficient management of the funds (WRM Report, 1999).

Topics Recommended for Further Exploration

- Ensure that Wingra spring monitoring is consistent and collecting an adequate amount of data that can be used for determining spring flow
- Address high chloride levels entering the groundwater from the Odana Ponds via:
    - Reducing infiltration when high chloride levels are present in Odana Pond
    - Reducing the amount of salt being used to clear ice and snow from roads and parking lots in the surrounding watershed and/or
    - Increasing the amount of infiltration from other sources such as rain gardens
- Use storm water utilities to incorporate innovative storm water management practices, educational programs and public involvement activities
- Create a storm water utility advisory board with citizen representation, watershed coordinators, fee-reduction incentives for both residential and non-residential properties and a small grants program for watershed education and restoration projects

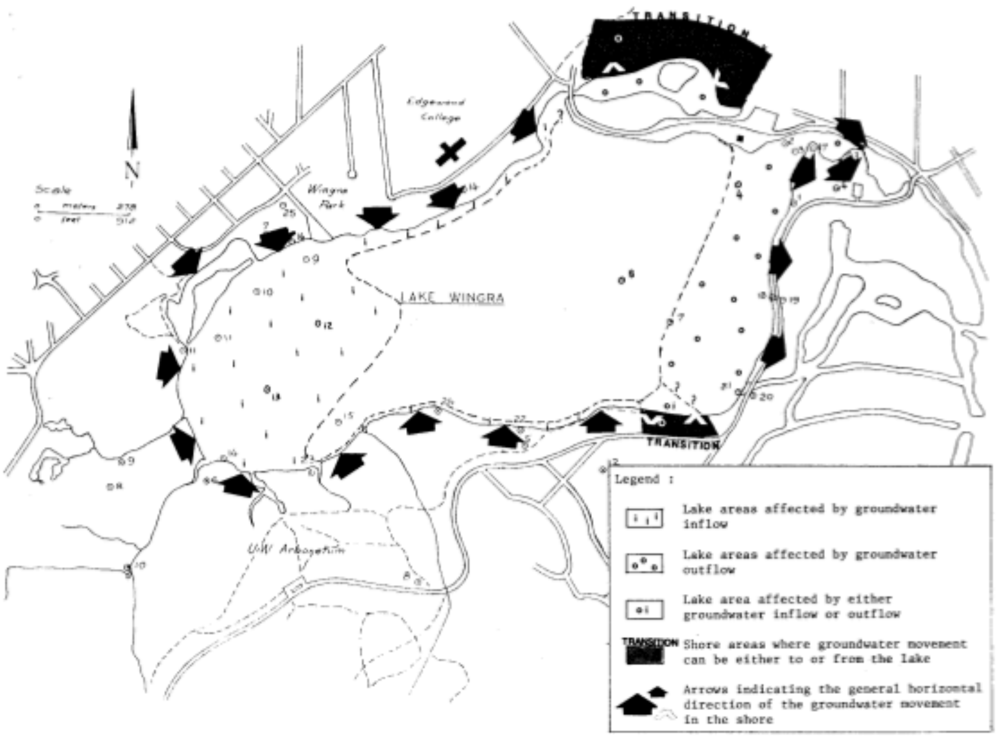
3 - Hydrology

Many factors, both natural and human induced, affect the hydrology of the Lake Wingra watershed such as the topography, bedrock geology and construction of dikes, locks and spillway, etc. These factors, in turn, affect the groundwater storage and infiltration capacity. The last glaciation period between 13,000 to 15,000 years ago lowered the relief in the Madison area creating a landscape of moderate slopes and poorly developed drainage networks, as can be seen in the Lake Wingra watershed (WRM Report, 1999). Lake Wingra and surrounding wetlands are composed of lucustrine deposits that formed the bed of Glacial Lake Yahara, a large glacial lake (WRM Report, 1999; Mickelson and McCartney, 1979). Other deposits in the Wingra Watershed include ice-contact stratified deposits, drumlins, ground moraines, and end moraines (WRM Report, 1999; Mickelson and McCartney, 1979). Once surrounded in ceremonial mounts constructed by the Ho-Chunk people, Lake Wingra and the adjacent wetlands were estimated to be approximately four times larger than the present size (Lake Wingra: A Vision for the Future, 2009).

Several individuals have conducted hydrological budgets of Lake Wingra, with some variation. Novitzki and Holmstrom (1979) estimated the following water budget based on data from January 1972 to September 1977 (WRM Report, 1999):

- Inflow: 31% direct precipitation, 34% runoff, 35% groundwater inputs
- Outflow: 70% outlet to Wingra Creek, 26% evapotranspiration, 4% groundwater outflow

All hydrologic budgets conducted have agreed that the groundwater in the basin flows from west to east.

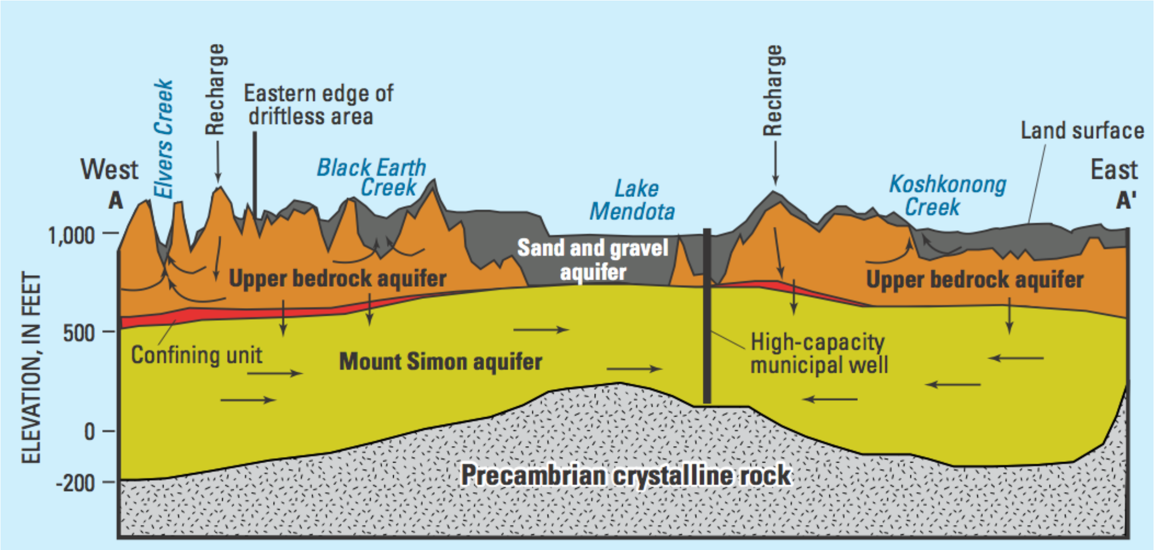


Pennequin and Anderson 1983

4 - Groundwater Storage

> *"Aquifers are geologic units (sand and gravel, sandstone) that can store and transmit significant quantities of groundwater."*
> *Ken Bradbury Presentation, 2011*

Groundwater is an important and historically abundant resource in the Madison area. Below the Yahara Lakes, there are three aquifers: a sand and gravel aquifer, an uppder bedrock aquifer and a lower bedrock aquifer. Glacial deposits and recent stream sediments form the shallow sand and gravel aquifer (Lathrop et al., 2006). Dolomite and sandstone form the upper bedrock aquifer, while the deep, Mount Simon aquifer is made of well-sorted sandstones (Swanson et al., 2006). The upper aquifer is the source for the springs in the Lake Wingra watershed.

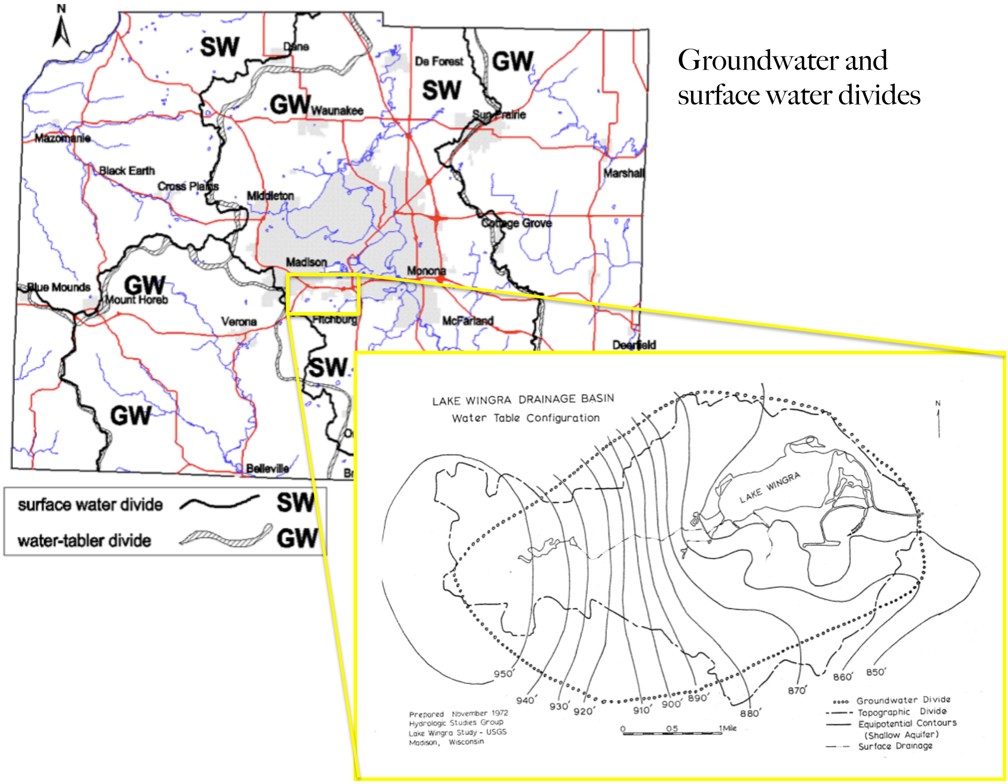


Bradbury et al., 2001

An important, leaky confining unit, called the Eau Claire aquitard (shown in red above), separates parts of the upper and lower aquifers throughout Dane County (Hunt et al., 2001). The exact thickness and presence of this aquifer is unknown ranging from over 60 ft thick in northwestern Dane County to absent in northeast Dane County (Bradbury et al., 2010). In the Yahara lakes area, the aquitard appears patchy and partially absent (Bradbury et al., 2010).

The presence or absence of this aquitard has implications for surface water and groundwater connection. In much of the Madison area, the groundwater is hydrologically connected to surface water and can either recharge or draw from the lakes, rivers and wetlands (Hunt et al., 2001). Without intervention, ground and surface water are in state of approximate equilibrium (Fetter, 2001). Historically, Madison lakes, rivers and wetlands were sinks supported by the abundant quantity of groundwater (Lathrop et al., 2006). Today, the lakes lose water to the groundwater system, which may allow contaminated lake water to enter groundwater.

Like surface water divides, groundwater has defined regions of flow at multiple scales called groundwater divides. Depending on the geology and other factors, groundwater divides do not always align with surface water divides. As illustrated below, the boundaries of Dane County's and Lake Wingra's surface water and groundwater divides do not overlap (Bradbury et al, 2010; Pennequin and Anderson, 1983). Moreover, these boundaries can be affected by a change in the recharge and discharge of the groundwater as well as topography (Pennequin and Anderson, 1983).



Groundwater and surface water divides

Bradbury et al., 2010; Pennequin and Anderson, 1983

The Mount Simon Aquifer, the deepest known aquifer beneath Lake Wingra, extends beyond the boundaries of Wisconsin. High capacity wells in the Madison area pump water from this deep well.

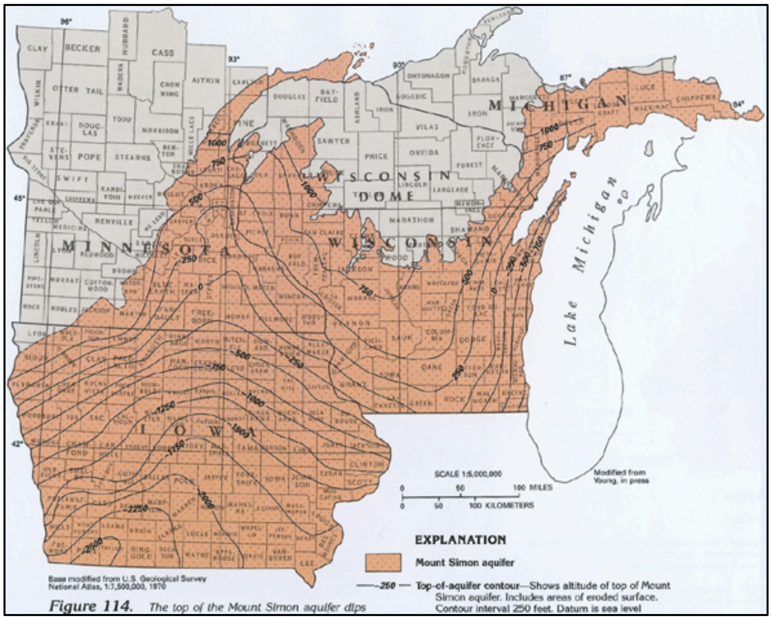


Figure 114. The top of the Mount Simon aquifer dips

USGS, 1970

5 - Groundwater Recharge

> *"Groundwater recharge is the entry of water at the water table surface, into the saturated zone, and the associated flow away from the water table surface within the saturated zone."*
> Sue Swanson, 1996

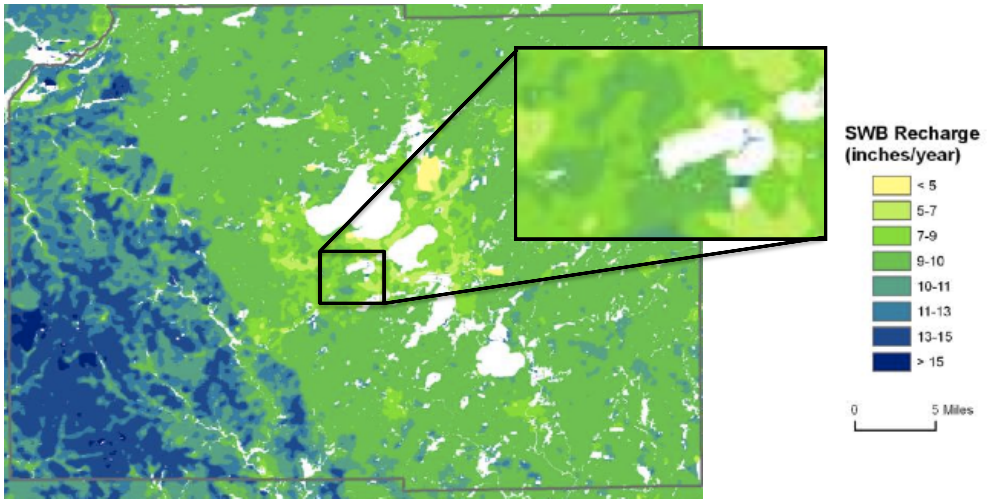
Groundwater recharge is dependent on many factors including precipitation timing and intensity, geology, climate, soils, topography, vegetation, and land use (Swanson, 1996). Recharge cannot be understood without considering groundwater discharge, or the removal of water from the saturated zone, across the water table surface (Swanson, 1996). Precise mapping of groundwater recharge and discharge is challenging and researchers are still working to develop accurate methods of characterization (Bradbury et al., 1999). Two methods used by Swanson (1996) in her master's thesis are listed below:

- **Water budget method** (developed by Stoertz and Bradbury) - Estimates the distribution of recharge rates and areas using a groundwater flow model; recharge areas accurate, but rates are not

- **Soil-water balance method** (developed by Krohelski and Bradbury) – Generates quantitative estimates of recharge rate; does not take groundwater flow system into account; recharge rates are accurate, but the method does not distinguish between recharge and discharge

The conversion of the Lake Wingra watershed from oak savanna vegetation cover to farmland to urban landscape has greatly affected the recharge rates in Dane County. Present estimates of the average recharge rate in Dane County range from 2.6 in/yr to 11 in/yr (Bradbury, 1999; Swanson, 1996). According to Ken Bradbury, recharge occurs everywhere in Dane County (Bradbury, personal interview). However, some areas have higher rates of recharge, particularly higher elevations such as hills, broad ridges and steep wooded slopes (Bradbury et al, 1999). Lower areas of the land are often areas of discharge.

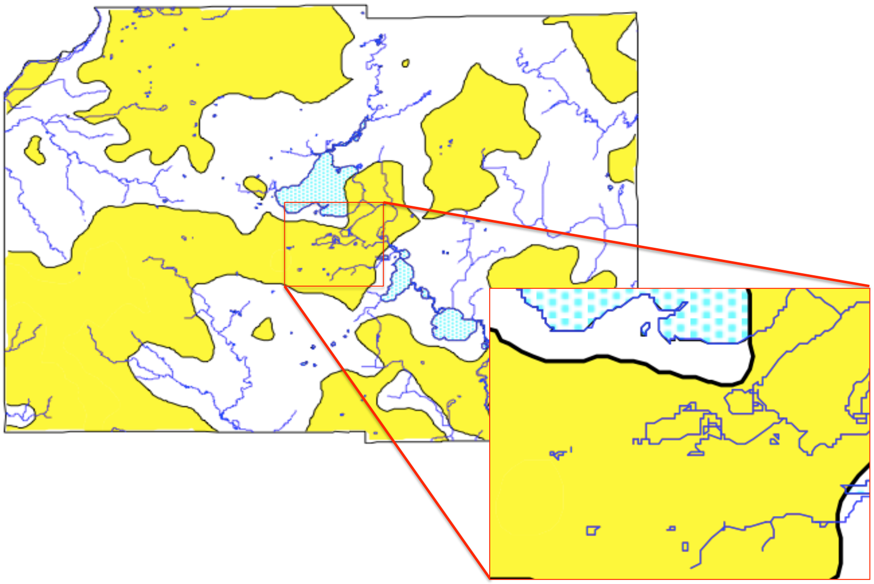
Dane County Recharge based on Soil-Water Balance Model



Bradbury Presentation, 2011

Besides surface water infiltrating into the upper aquifer, water from the upper aquifer can also penetrate into the deep, Mount Simon aquifer. To determine areas of recharge of the deep aquifer, Bradbury et al (1999) superimposed the elevation of the water table with the potentiometric surface (determined by water pressure) of the Mount Simon aquifer (Bradbury et al, 1999). Areas of recharge were designated where the potentiometric surface was below the groundwater table.

Areas of recharge to the Mount Simon Aquifer based on water level measurements



Bradbury et al., 1999

Identifying areas to target for recharge projects will be important for the Wingra Watershed Management Plan. According to one interviewee, the southeast marsh may be a potential area for future surface water infiltration since a considerable amount of storm water runoff is directed to this marsh. A few years ago, when the area was being reconstructed, a pond with a clay liner was installed in the marsh to prevent potentially contaminated water from reaching a municipal well. Many individuals were disappointed with the presence of the clay liner seeing reconstruction as an opportunity to install a rain garden or constructed wetland.

The southwest marsh is an example of a complex water management conundrum. The Lake Wingra watershed would greatly benefit from increased infiltration; however, if the water is contaminated, the infiltration could compromise the quality of Madison drinking water. Water quality and quantity issues are not separable and must be analyzed and solved in tandem using many methods of analysis (i.e. recharge models, groundwater flow models, risk assessment, precautionary principle, ecological design, ecological restoration, etc.).

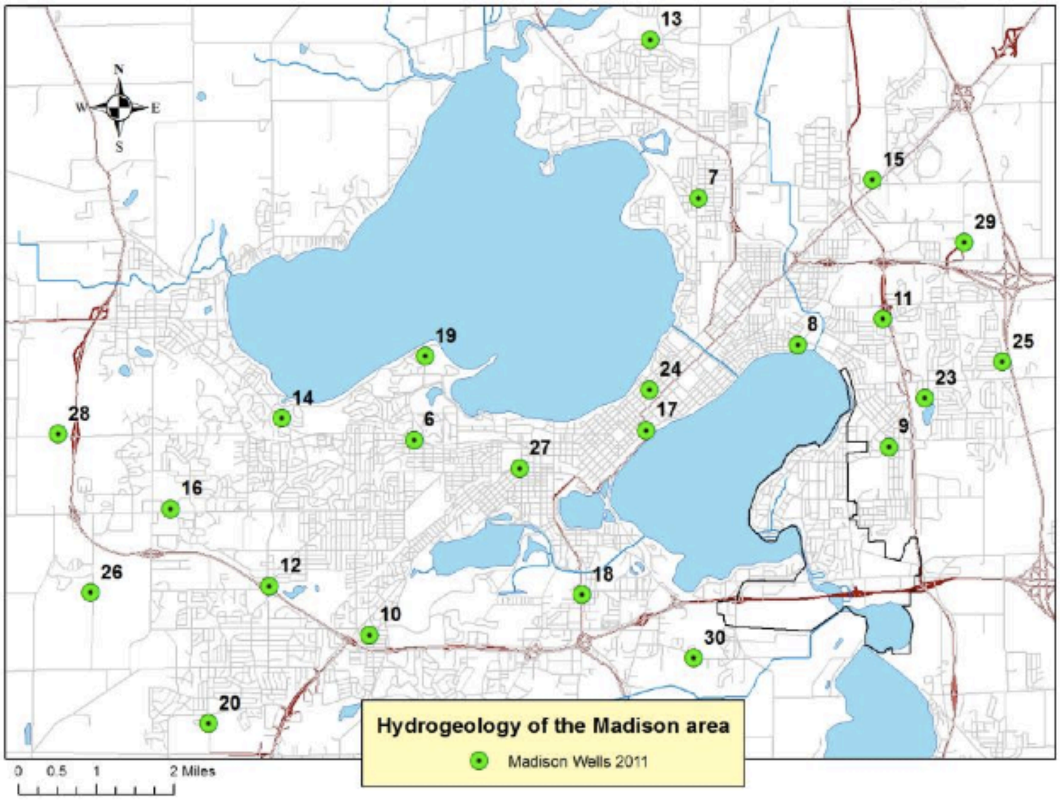
Green infrastructure offers unique and effective ways to increase infiltration, reduce groundwater consumption, and reduce runoff. A few examples of successful green infrastructure project in other U.S. cities include installing the following: parking lot swales to biofilter stormwater, rain barrels and native landscaping, underground cisterns, filter boxes underneath turf grass, plastic chambers called Infiltrators or StormTech chambers and GravelPave or porous gravel material. Using the methods of analysis listed above as well as green infrastructure can help local decision makers make informed decisions pertaining to complex water management.

Topics Recommended for Further Exploration

- Identify areas of opportunity for recharge projects (southeast marsh and the Arbor Hills greenway)
- Install permeable surfaces throughout the watershed
- Develop of infiltration standards
- Incorporate green infrastructure into the Wingra Watershed Management Plan
- Encourage the city to distribute grants for on site stormwater management
- Give citations to property owners that create excessive runoff

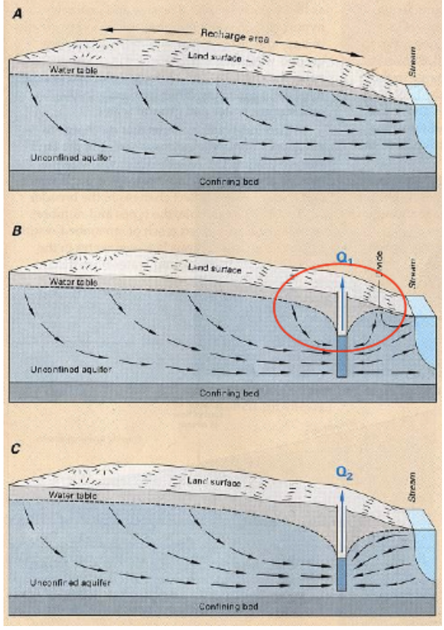
6 - Water Consumption & Disposal

Besides the decrease in infiltration, high capacity well water consumption affects groundwater levels and spring flow as well. As shown below, high capacity wells are located throughout the Madison area.



Bradbury Presentation, 2011

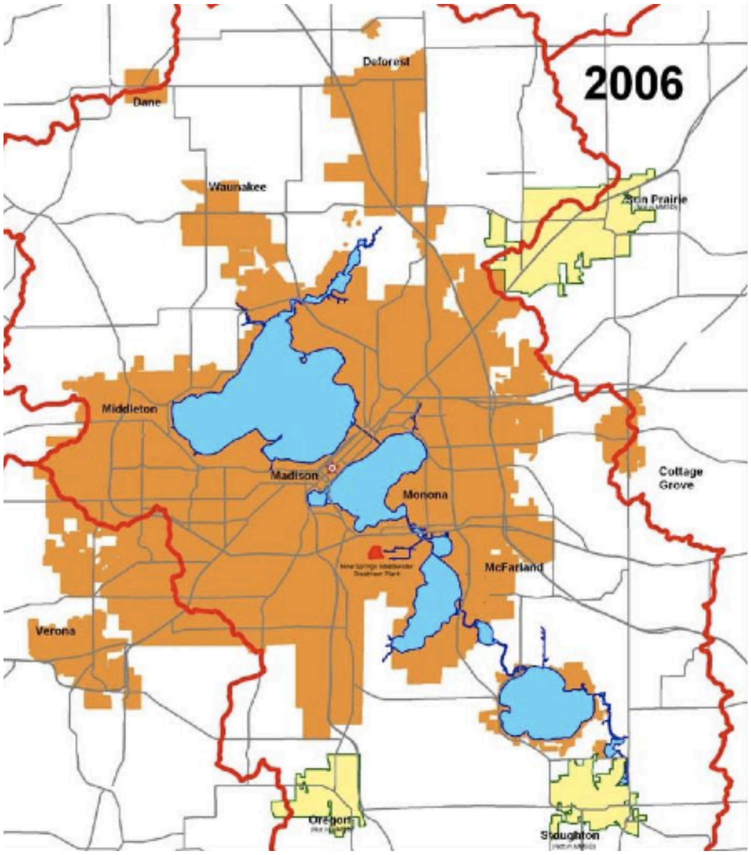
On average, Madison's municipal and industrial wells consume approximately 50 million gallons of groundwater per day. The affects of groundwater use include alteration of groundwater flow paths, effects on surface water, effects on water quality and effects on water table reducing flows in streams and water tables in wetlands (Bradbury Presentation, 2011). High capacity wells have the potential to reduce or eliminate spring flow.



The City of Madison Water Utility controls Madison's municipal wells; thus, the City of Madison Engineering is not involved in groundwater projects beyond monitoring potentially contaminated waste sites in Madison. The City of Madison Engineering monitors remediation at five closed landfills where underground gas and leachate collection systems operate 24 hours per day (Brynn Bemis, personal interview).

In 2008, the City of Madison Water Utility put together a Conservation and Sustainability Plan to cut down on water use. This plan involves a toilet rebate program and discusses altering the water utility rate structure. The Water Utility also has a Private Well Abandonment Reimbursement Program to prevent groundwater contamination from unused, unsafe or non-complying wells since domestic wells provide an opportunity for surface contaminants to reach the groundwater at an alarming rate (Bradbury, personal interview; City of Madison website). According to Bradbury et al. (2010), many unabandoned private wells still exist within the city of Madison.

After well water is consumed by local residents, Madison's (and other neighboring communities') wastewater is treated at the Madison Metropolitan Sewerage District (MMSD) plant at Nine Springs. This water is discharged to Badfish Creek, a creek outside of the Yahara drainage basin (Bradbury Presentation, 2011). This displacement of water contributes to declined water levels in the groundwater system (Lathrop et al., 2006).



Bradbury Presentation, 2011

This past year, the UW-Madison Water Resources Management (WRM) graduate students have been working with MMSD and the City of Fitchburg and its residents to evaluate the potential for using recycled treated water from the Nine Springs Wastewater Treatment Plant to recharge groundwater in the City of Fitchburg (WRM Program website). Water recycling is one way to increase groundwater recharge.

Topics Recommended for Further Exploration

- Support collaboration between the Water Utility and the City of Madison Engineering. Currently water quality and quantity issues are separately handled. A more integrated approached would allow for efficiency and long range planning
- Determine whether or not drawdown is decreasing or leveling off. If leveling off, how does the level affect spring flow
- Determine whether any of the landfill waste sites are located in or upstream of the Lake Wingra Watershed. If so, ensure that the updated Dane County groundwater model can track leachate

7 - Shallow & Deep Aquifer Connections

In 1978, McLeod et al. found that wells connected to the deep, Mount Simon aquifer dropped from 22.5 feet from 1882 to 1975, while water levels in the shallow bedrock aquifer dropped 3-6 meters (McLeod, 1978). These results provide supportive evidence that the shallow and deep aquifers are connected.

More recently, Bradbury et al. (2010) discovered that viruses in sewage could be traced within groundwater samples from the deep aquifer. This study determined that deeply cased municipal wells in confined aquifers could be susceptible to pathogen contamination (Bradbury et al., 2010).

> *"It is clear from these results that casing these deep wells across a regional aquitard (the Eau Claire aquitard) does not prevent virus contamination, or even significantly reduce the percentage of virus detections. However, the absolute concentrations of viruses (in gc/l) were appreciably lower in two of the deeply cased wells (wells 13 and 30) than in the other wells sampled, and…larger casing depth appears to be correlated with lower virus concentrations (Bradbury et al. 2010)."*

The three most likely pathways for contaminants are 1) transport through the aquitard by porous-media flow, 2) transport by porous-media flow around the edge of the aquitard or through nearby "windows" or breaches in the aquitard, including local lakes, and 3) transport by rapid flow through fractures in the aquitard or through cross-connecting nearby wells (Bradbury et al., 2010).

The connection between the upper and lower aquifer has substantial implications for the City of Madison: 1) surface water contaminants may enter the drinking water of Madison residents and 2) the high prevalence of viruses detected in the groundwater may indicate that sewage leakage (including pathogens, toxic chemicals, pharmaceutical compounds, etc) is entering the groundwater. Perhaps the updated groundwater model will lead to a greater understanding of how the upper and low aquifers are connected. This discovery may help to increase governmental and residential awareness about the importance of repairing sewage piping and keeping the upper aquifer clean.

Topics Recommended for Further Exploration

- Ensure that Wingra Watershed Management Plan decision are informed of the shallow and deep water connections

8 - Groundwater Models: 1994 & 2012

In 1994, the Wisconsin Geological Natural History Survey (WHNHS) completed the Dane County Groundwater Model. This model was constructed using the model code MODFLOW and much historic data. The 1994 model encompassed Dane County and eight adjacent counties in south central Wisconsin. This purpose of this model was to assist the "future water resource management decision making on an ongoing basis (Bradbury et al., 1998)." Thus far, the model has been used to complete the following tasks (the last four bullets are model limitations):

1994 Model

- Simulate pumping rates from 93 high capacity wells
- Estimate recharge distribution in Dane County and other adjacent counties in south central Wisconsin
- Estimate amount of groundwater discharging to surface water bodies
- Predict groundwater flow rates
- Assess the effects of existing and potential groundwater withdrawals and effects of proposed water-management programs
- Improve understanding of groundwater system and relation to groundwater
- Predict water level changes or trends and changes in stream gains and losses that result from change in land and water use
- Contains low 40 acre resolution
- Limited availability of data for certain parts of the model area (particularly in the western part of model area)
- Limited boundary conditions
- No time-dependent capabilities

For the last year, Mike Parsen at WGNHS has been updating the Dane County Groundwater model. The anticipated date of completion is the summer of 2012. The new model will expand the capacity of the 1994 model in the following ways (as listed by Bradbury, 2009):

2012 Model

- Higher resolution
- Transient or time dependant capabilities allowing more detailed analysis of management scenarios (i.e. can include impacts of short climatic events like seasonal droughts or floods, infiltration events, lake level changes, and pumping schedules)
- Updated and recalibrated pumping rates of municipal wells
- More accurate representation and analysis of upper bedrock units including the high-conductivity zones in the Tunnel City Formation
- More accurate representation of the Eau Claire aquitard and connection between the shallow and deep aquifer systems
- Ability to include major springs in the county and to simulate the impacts of pumping and land-use changes on springs
- Improved detail of flow paths near water supply wells
- Overall better model calibration techniques not previously available
- Incorporates data from Sue Swanson's Nine Springs Model

Topics Recommended for Further Exploration

- Ensure that the 2012 model can more accurately trace contaminate transport from Odana Ponds Project
- Communicate with Mike Parsen on any additional recommendations for the 2012 model or model questions

9 - Groundwater Policy

> *"Wisconsin lakes and rivers are public resources, owned in common by all Wisconsin citizens under the state's Public Trust Doctrine. Based on the state constitution, this doctrine has been further defined by case law and statute. It declares that all navigable waters are "common highways and forever free", and held in trust by the Department of Natural Resources."*
> -Department of Natural Resources webpage

Below is a brief summary of groundwater laws and accompanying regulatory programs for the State of Wisconsin and City of Madison, respectively. Definitions were taken directly from the DNR's online summary:

1983 Wisconsin Act 410, Wisconsin's Comprehensive Groundwater Protection Act

This act was the first major law to expand Wisconsin's "legal, organizational, and financial capacity for controlling groundwater pollution. " The major components of the act are as follows:

- **Standards**: The DNR established groundwater standards in chapter NR 140, Wisconsin Administrative Code
- **Regulatory programs**: Established at DNR, DOC, DOA, DATCP and DOT
- **Aquifer Classification**: Deliberately omitted so all aquifers are protected equally
- **Monitoring and Data Management**: Created under s. 160.27, Wis. Stats.
- **Research**: The UWS, DATCP, DNR and Commerce have participated in a joint solicitation for groundwater-related research and monitoring proposals since 1992 (see http://dnr.wi.gov/org/water/dwg/gcc/Research.htm)
- **Coordination**: Groundwater Coordinating Council was created to advise and assist state agencies in the coordination of non-regulatory programs and the exchange of groundwater information
- **Local Groundwater Management**: Clarified the powers and responsibilities of local governments to protect groundwater in partnership and consistent with state law

2003 Wisconsin Act 310, Wisconsin's Groundwater Protection Act

This act expanded the State's authority "to consider environmental impacts of high capacity wells and established a framework for addressing water quantity issues in rapidly growing areas of the state. Act 310 recognizes the link between surface water and groundwater, and the impact wells may have on groundwater quality and quantity (DNR online summary)."

- Ch. NR 820 formally defines the extent of Groundwater Management Areas
- Limitation – Fails to protect 99% of the state's lakes, 97% of springs, 92% of rivers and 100% of wetlands (Wisconsin Alliance)

Great Lakes Compact

This compact addresses water quantity management in the Great Lakes – Saint Lawrence River Basin.

2007 Wisconsin Act 227

This Act 227 calls for statewide registration of existing and new water withdrawals with the capacity to withdraw more than 100,000 gallons per day averaged over 30 days. Withdrawals over 100,000 gallons per day averaged over 30 days must be reported annually. This act also requires that the DNR develop and implement a water conservation and efficiency program with voluntary measures to apply across the state, additional mandatory elements that apply in the Great Lakes Basin.

High Capacity Well Program (NR 820)

This Program gives DNR the authority to establish a permitting program for high capacity wells. NR 820 is the administrative rule that implements the legislative intent of Act 310. This rule outlines the permit process, which permit applications may warrant additional review, how decisions are made to grant approval for a high capacity wells and/or under what conditions high capacity wells can operate.

Supreme Court Decision: Lake Beulah v. DNR, 2011

Department of Natural Resources (DNR) has the authority and a duty to consider potential adverse impacts posed by proposed high capacity wells if presented with concrete, scientific evidence of the potential for harm to state waters during the well permitting process.

City of Madison – Private Well Abandonment Reimbursement Program

This Madison General Ordinance Section 13.21 addresses Wisconsin Administrative Code, Chapter NR 812. This ordinance, effective January of 2010, aims to prevent groundwater contamination of the aquifer supplying City of Madison drinking water wells from unsafe, unused, or non-complying private wells.

Topic Recommended for Further Exploration

- The policies listed above can help support the Wingra Watershed Management Plan. Keep the policies in mind when developing implementation plans.

10 - Recommendations - Consolidated

Topic 2

- Ensure that Wingra spring monitoring is consistent and collecting an adequate amount of data that can be used for determining spring flow
- Address high chloride levels entering the groundwater from the Odana Ponds via:
    - Reducing infiltration when high chloride levels are present in Odana Pond
    - Reducing the amount of salt being used to clear ice and snow from roads and parking lots in the surrounding watershed and/or
    - Increasing the amount of infiltration from other sources such as rain gardens
- Use storm water utilities to incorporate innovative storm water management practices, educational programs and public involvement activities
- Create a storm water utility advisory board with citizen representation, watershed coordinators, fee-reduction incentives for both residential and non-residential properties and a small grants program for watershed education and restoration projects

Topic 5

- Identify areas of opportunity for recharge projects (southeast marsh and the Arbor Hills greenway)
- Install permeable surfaces throughout the watershed
- Develop of infiltration standards
- Incorporate green infrastructure into the Wingra Watershed Management Plan
- Encourage the city to distribute grants for on site stormwater management
- Give citations to property owners that create excessive runoff

Topic 6

- Support collaboration between the Water Utility and the City of Madison Engineering. Currently water quality and quantity issues are separately handled. A more integrated approached would allow for efficiency and long range planning
- Determine whether or not drawdown is decreasing or leveling off. If leveling off, how does the level affect spring flow
- Determine whether any of the landfill waste sites are located in or upstream of the Lake Wingra Watershed. If so, ensure that the updated Dane County groundwater model can track leachate

Topics 7

- Ensure that Wingra Watershed Management Plan decision are informed of the shallow and deep water connections

Topic 8

- Ensure that the 2012 model can more accurately trace contaminate transport from Odana Ponds Project
- Communicate with Mike Parsen on any additional recommendations for the 2012 model or model questions

Topic 9

- The policies listed above can help support the Wingra Watershed Management Plan. Keep the policies in mind when developing implementation plans

11 - Conclusion

There is no "away"...no isolated containers that do not eventually leak. Not when the population continues to grow and all social, economic, and environmental systems intertwine into a cacophonic symphony.

The current state of spring and groundwater flow in and beneath the Lake Wingra watershed is a direct result of the prevailing culture. Madison residents have valued uninhibited quantities of clean, clear *drinking* water, paved surfaces for convenient transportation and snow-free streets in the winter. However, the preserving healthy Madison lakes, land and ecological support systems have been a secondary priority. Moreover, the common language for understanding these natural systems is lacking. The average citizen may not have the ability to conceptualize where their water comes from and the effects of municipal well pumping – let alone the understanding of surface water and groundwater interactions.

Adapting a common framework can help guide future thought concerning water resources management in the Lake Wingra Watershed. Aldo Leopold's land ethic is one such example. As written in *A Sand County Almanac*, "A land ethic...reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land...The land ethic simply enlarges the boundaries of the community to include soils, waters, plans and animals, or collectively: the land."

Maintaining adequate quantity and quality of groundwater for the health of current and future city residents and ecosystems will require no less than a common framework, the knowledge bases and tools summarized in this report coupled with strong leadership and social innovation. Fortunately, the Wingra community leaders are taking great steps forward by continuing to conduct research, updating the Dane County groundwater model, creating water conservation, rain garden and other programs, establishing supreme court decisions in favor of ecosystem health, and creating a Wingra Watershed Management Plan. Let this report be a salute to all the hard work that has brought us to our current status and encourage readers to carry the process forward.

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