Mid-West

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One of the things I am going to do is first describe the resources that we have in the midwest. These resources are quiet resources. These resources are basically different than what we see in the New England states. We have great changes as a result of the lowering of the SO_2 emissions.

Basically, what we are concerned about for aquatic resources in the upper midwest are seepage lakes. I want to tell you a little bit about seepage lakes and how they work.

This is typically a seepage lake in the upper midwest (Figure 1). You can guess the name of it, Round Lake. Basically, what we see is no surface inputs. It is basically what falls out of the sky from a hydrologic point of view and what comes in from the groundwater system (Figure 2).

We selected a few of these seepage lakes and modeled them extensively.

Figure 1. Round Lake.

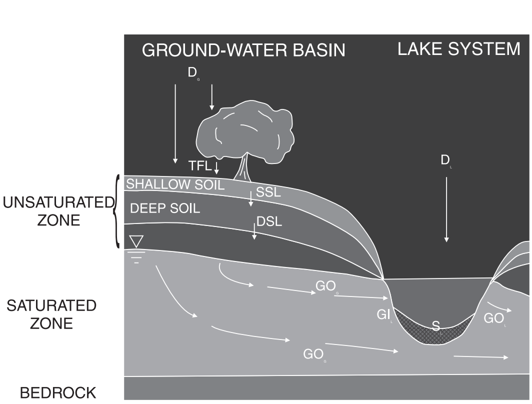

Figure 2. Hydrology of a seepage lake system.

This is one of the modeling efforts, Round Lake, where we took a look at what falls out of the sky, what goes through the trees, down into the soils, into the groundwater system, and the processes in the lake itself, to try to figure out the mechanics of acid rain.

In New England the soils have been damaged to the point where you don't have any weatherable materials left, your base saturation is pretty low. In Wisconsin, that is not necessarily true. We do have sandy, loamy soils. Take a look at this table (Table 1), it will give you an idea.

The base saturation index is about 30 percent. The Adirondacks is around 10. So, we have some base cations left, and we are still holding our own as far as the soils go, although we don't want to go any lower than this, if we can help it. The pH of the soil solutions down around eight centimeters in Wisconsin are running about 5.6 to 6.1. Down about 60 centimeters, 6.5 to 6.7. Compare that to the Adirondacks, where you see that the pH of the soil solution is much lower, much more acidic.

One of the biggest features with these seepage lakes, is the graphic watershed which, in this case, is the dashed line around the outside of Round Lake (Figure 3). It does not influence the chemical constituents coming into the lake.

The sandy soils would absorb any water. We had no surface run off coming into these lakes. It was the groundwater contributing basin. You can see the arrows coming in. They defy the concept that what falls in the topographic watershed is the only important issue here. You have to go beyond that. It is what falls into the groundwater contributing area that really counts. So, groundwater becomes an important issue here.

Table 1. Wisconsin soils.

Omega Loamy Sand

BSI ~ 30%　　<10%Adirondacks

Soil Solution pH

	Wisconsin	Adirondacks
8 cm	5.6 - 6.1	3.6 - 3.9
60 cm	6.5 - 6.7	4.7 - 4.9

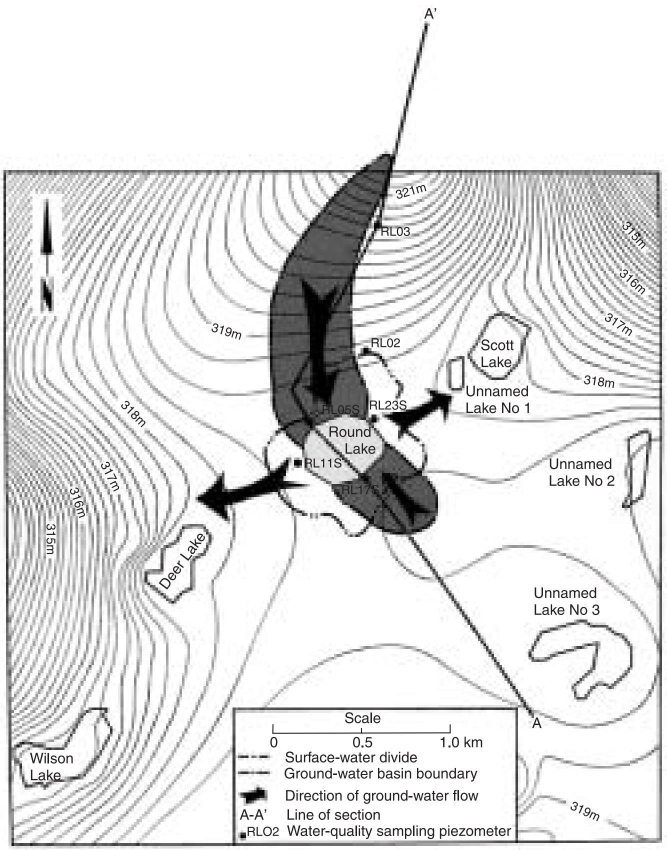

Figure 3. Groundwater flow in and out of Round Lake.

We did some model runs. This is with an EPRI funded project.

This is another lake that has an ANC of around 25, Vandercook Lake (Figure 4). You see in the solid black line what you would normally predict, what we would see from the present situation. In the dashed line is basically what we called the sensitivity. We made a sensitivity run with the groundwater out. You can see that with the groundwater out of this situation, the lake would go acidic.

I don't always believe in models until we verify them. So, we went to one of our acidic lakes and put wells around it to show that there was no groundwater moving in.

We put a well down, a high capacity well, and we pumped water in (Figure 5). We can control the volume, we can control the chemical inputs into the lake and we will see if our model really holds.

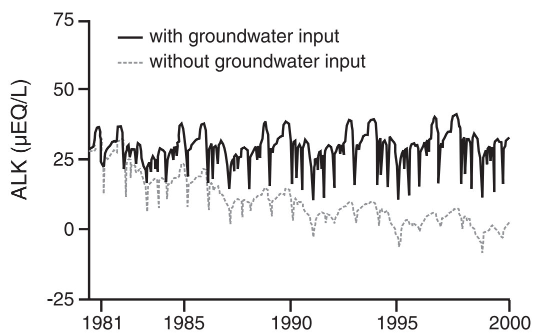

Figure 4. Vandercook Lake alkalinity with and without groundwater input.

Basically, we pumped the groundwater in with sprinklers. The groundwater is colder in the summertime than the surface waters. We didn't want it to just sink to the bottom. So, we put out sprinklers around the lake, basically, not very large volumes.

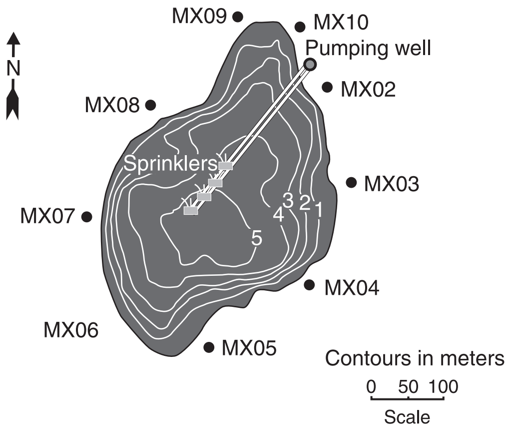

Figure 5. Location of groundwater well around Max Lake.

The background, the pH of the lake was 5.1 and the alkalinity, A and C, was negative.

As we put more and more groundwater in, of course, we changed the pH and the alkalinity, as you might expect (Figure 6). So, once again, it confirmed the model. In these lakes in the midwest that we are concerned about, groundwater is extremely important as far as buffering capacity goes.

Morgan Lake, is a lake that sits above the ground water table, a mounted situation, we call it (Figure 7). These are the ones that we are concerned about. We have no groundwater inputs to them. Basically, hydraulically, they receive everything out of the sky. These are the ones we find that are acidic in the state, and in the upper peninsula of Michigan.

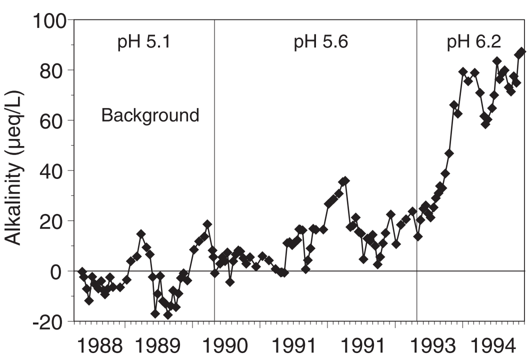

Figure 6. Alkalization of Max Lake.

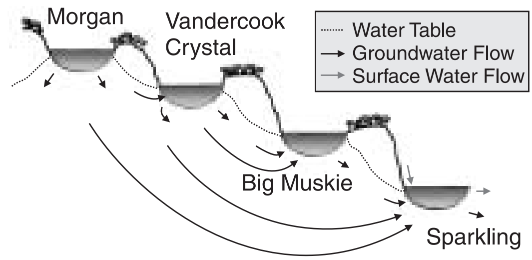

Figure 7. Relative landscape position of Wisconsin Lakes.

As you get more and more groundwater, like Vandercook, Crystal, Big Muskie, and work our way down to Trout Lake, the pH goes down and the alkalinity goes up, all down that chain.

Finally, we start getting surface water inputs like at Trout Lake, a pretty hard water lake that we don't have to worry about. So, we are concentrating basically on the impacts on lakes like Morgan Lake.

In our state in 1986, we had legislation passed, a reduction in SO_2 that was mandated by 1993, a 50 percent reduction in our SO_2 emissions, going from 650,000 tons of SO_2 down to 325,000.

The utilities were at about 500,000 and they reduced to 250,000 tons of SO_2 . As a result of that, and also with national legislation that came along in the 1990s, we did achieve by 1993, a 50 percent reduction and we have maintained that as far as SO_2 reduction goes in the state.

Now we will take a look at the impacts (Figure 8). If you take a look at the upper left hand corner, that is the sulfate deposition, kilograms per hectare per year, with time along the bottom. You can see that there is a tremendous reduction. We are down to levels now that are less than 10. We are talking about eight kilograms per hectare per year. We used to figure 10 was the magic number and if we got below that, we would start saving our resources.

In contrast to that, I was looking at the NADP stuff for the northeast, and they are still going from 40 to 30. So, there is still a long way to go. We do have much lower loading levels.

There have been some slight increases in the pH .

Now, also looking at the resources, I will give you a summary (Figure 9). Looking at box plots here, 1988 the sulfate on the left-hand side, versus 1997. You can see there was a decline in these lakes, basically in the sulfate.

If you look at the pH, there is definitely an increase in the pH of these clear water sensitive lakes.

This basically summarizes significant trends (Figure 10). Again, it is just reiterating what I just told you.

The last figure (Figure 11), there are other things that helped control our acidity in these lakes

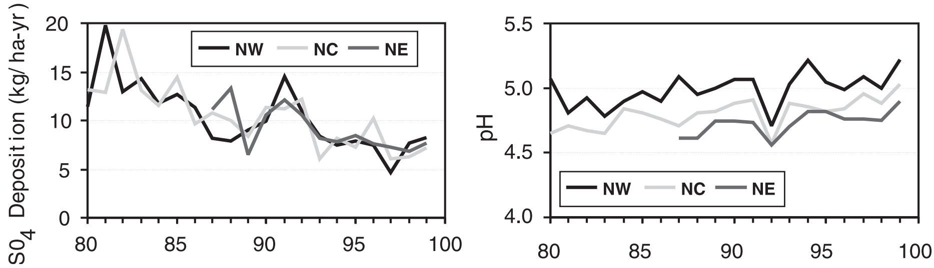

Figure 8. Acid deposition in Northern Wisconsin. Sulfate deposition has declined by ~50% since 1980. There has been an ~0.3 unit increase in pH since 1980. NADP data.

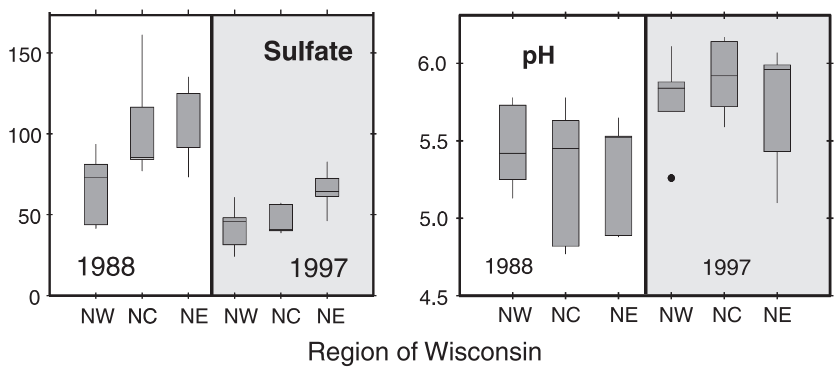

Figure 9. Decadal responses of clear-water lakes across Northern Wisconsin to decreased deposition. In 1988, lakes of similar pH had higher [SO4] in NC and NE. Over 10 years, SO4 decreased and pH increased in all regions. The largest declines in SO4 have been found to the east.

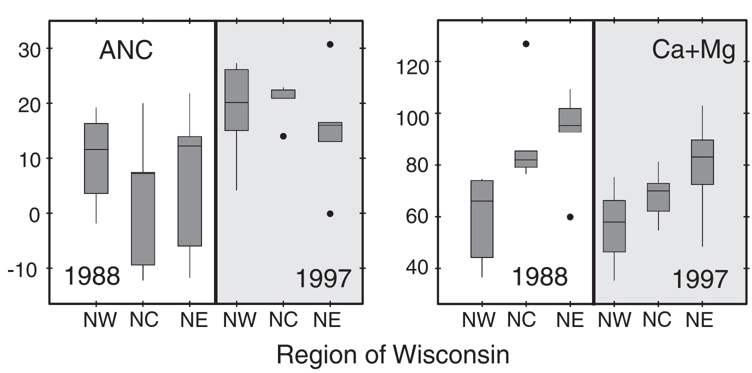

Figure 10. Delayed recovery due to cation decreases. There have been only small increases in ANC over the decade. Cations have decreased over the same period, particularly in NC and NE. Like with SO_4, cation concentrations increase from west to east.

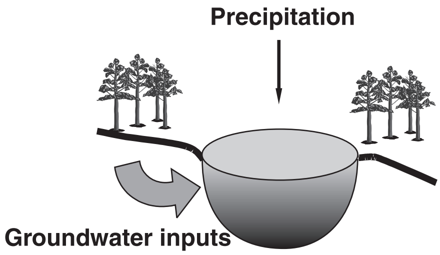

Figure 11. Sources of alkalinity and cations to seepage lakes. Other Issues. Climate change could reduce groundwater inputs of cations, causing lakes to become more sensitive to acid deposition.

that we have to be concerned about, and one of them is climate change.

If we get a change in the amount of precipitation that falls in the groundwater contributed areas of these lakes, and we either increase or decrease the groundwater inputs, it makes a difference in what the alkalinity is going to be in these lakes.

If we have a drought, which we had in some of these situations, we decoupled the groundwater from the lakes. We have actually seen the alkalinity, A and C, decline considerably.

We have great concern over climate changes and how this will impact our lakes also. So, there are a lot of features that come into play, although I think most importantly is the sulfate deposition.

Questions

MR. COWLING: Here is a state that put its money ahead of where its mouth was, I guess you could say, in the sense that you have committed yourself to decrease of emissions well in advance of the federal requirement to do so.

MR. KNAUER: Of course, the concern was how much falls locally versus how much comes in on a national basis. I think the position we are sitting in as far as the midwest goes, most of the high levels of sulfur dioxide emissions, of course, are going up into the northeast, thank goodness.

MR. SCHULER: John Schuler , American (sic) Department of Natural Resources. I was wondering if you looked at mercury in any of those lakes?

MR. KNAUER: Yes. We have been looking at mercury since 1988. If you want to get into that, that is another whole area. There is a relationship between the pH and the mercury you see in the fish. We first discovered that when we looked at Little Rock Lake as an acidification project. We actually divided the lake in half and acidified one side slowly over a number of years, six years. We did notice at that point in time when we did that, that the mercury on the acidified side versus the reference base was definitely significantly elevated. Is that because the pH itself is controlling that?

The sulfate side of it, the sulfate reducing bacteria are the methylators. This is methyl mercury, of course, that is in the fish so it has to be methylated first.

There is that definite relationship that is going on with acidity. If you increase the pH, where you start to change is maybe the methylation rate – not the methylation rate so much as probably the evasion.

If you lower the pH the Hg_2 that comes in has more opportunity to bump into the bacteria to be methylated. That is basically what we found in the Little Rock Lake experiment.