Article 88

Technical Note #102 from Watershed Protection Techniques. 3(1): 597-600

Return to Lake McCarrons

Does the performance of wetlands hold up over time?

How well does the pollutant removal performance of ponds and wetlands hold up over time? Some have speculated that it must decline, while others assume that it remains constant. Until recently, however, there has been no monitoring data to answer the question. Almost all pond and wetland monitoring studies have been one-time “snapshots” taken over a few years at most, and usually right after construction. Thus, any assumption about the future performance of a stormwater pond or wetland is simply an assumption. A recent study by Gary Oberts (1997) and his colleagues, however, sheds more light on what we can expect about the long term performance of stormwater ponds and wetlands.

Oberts returned to a Minnesota pond/wetland system that he had first investigated nearly a dozen years before. The Lake McCarrons system consists of two main stormwater treatment areas: a wet pond with a surface area of about 2.5 acres, and a six-acre linear wetland composed of five cells (Figure 1). The entire system provided about 0.32 inches of treatment storage, with about 40% allocated to the pond and 60% to the wetland cells. The treatment system had a large contributing drainage area (736 acres) which was 27% impervious. The predominant land use was single family residential homes, interspersed with some commercial development and highways.

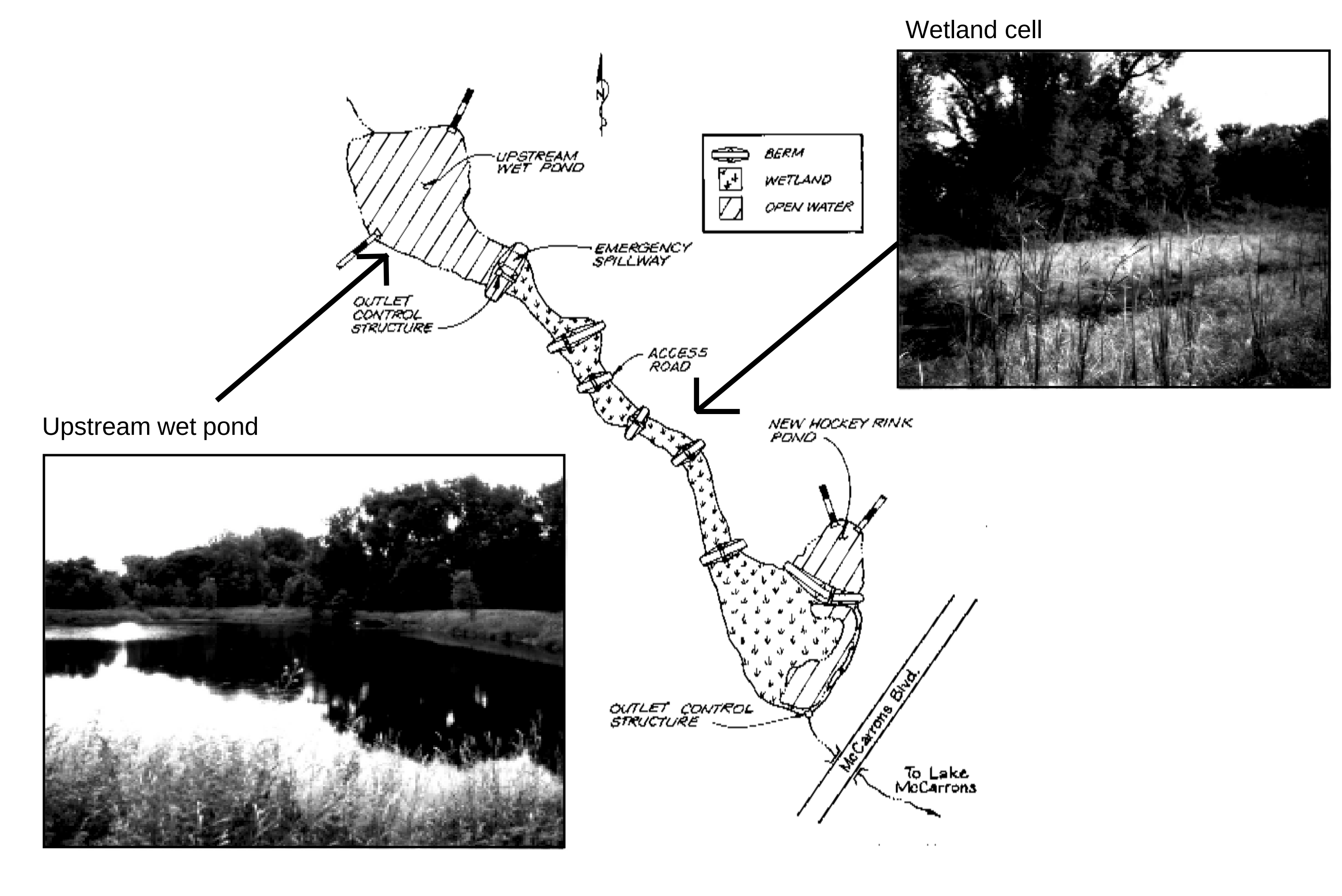

Figure 1: The McCarrons Pond Wetland System

Located near the twin cities of Minneapolis and St. Paul, the McCarrons system experiences cold and snowy winter conditions. While annual precipitation is modest (about 26 inches rainfall equivalent), much of it occurs as snow—about 50 inches each year. Cold winter temperatures present a major performance challenge for the system. A two foot thick layer of ice usually forms over the pond every winter, and ice also covers the wetland cells. The melt of the watershed snowpack creates a major runoff event in the spring, at a time when much of the system is still frozen and outlet structures are obstructed by ice.

Runoff and snowmelt events dominate the water balance at the McCarrons system (72% of total flow). Baseflow, which averages about 0.3 cfs, comprises the remainder of the total annual flow. About ten percent of the total flow was lost as it traveled through the system, presumably due to evaporation and infiltration.

The McCarrons system was constructed in 1985 and its performance was intensively sampled over the next two years (Oberts and Osgood, 1988). The original monitoring effort consisted of automated sampling of 21 rainfall and four snowmelt events, as well as four baseflow samples. The pond system exhibited remarkably high pollutant removal over this period, particularly given that the winter conditions and the loss of 18 percent of the pond capacity due to sediment deposition from upstream construction (Table 1). The reduction in sediment, phosphorus and nitrogen mass was 96, 70 and 58%, respectively. In each case, the removal of the McCarrons system was about 15 to 20% higher than the national average performance for pond and wetland systems (see article 64).

Nutrient removal was slightly greater in the pond than in the wetland cells, and during summer months as compared to the winter months. The very high phosphorus removal (70%) was believed to be due in part to the sapric peat subsoils that were exposed during the excavation of the system. These subsoils contained high amounts of peat and organic matter which may have been important binding sites for phosphorus, at least until the soils were either saturated or buried.

Ten years later, Oberts and his colleagues returned to Lake McCarrons, and sampled 35 storm and snowmelt events over a 22-month period, as well as quarterly baseflow quality samples. He employed essentially the same sampling effort and monitoring methods as were used in the first study, and therefore could compare how pollutant removal rates had changed over time.

The pond/wetland system and its catchment had changed in several ways in the 10 years since the first monitoring study. In particular, about 100 acres of new drainage area was connected to the system which fed into the system downstream of the headwater detention pond. Another small inlet pipe was directly connected to the last wetland cell in the system, which resulted in short-circuiting of this runoff through the system. In addition, several berms that formed the individual wetland cells had eroded, and flow across the entire wetland had begun to channelize. On the plus side, the main pond cell had been dredged to its original dimensions shortly before the second round of monitoring began (at a cost of $50,000).

The wetland community has also changed significantly over the years. Wetland species that had been originally planted in the cells were largely supplanted by invasive species, such as cattail, reed canary grass, purple loosestrife and duckweed. A recent wetland plant inventory indicated that 17 plant species were now colonizing the emergent zone, half of which were invasive species. Relict populations of bulrush, water lilies and water irises that were part of the original wetland planting plan could still be found in a few places. The characteristics of the wetland sediments had also changed substantially in the intervening years. Both iron and aluminum concentrations in pond and wetland sediments had declined sharply since 1985, indicating that the bottom sediments had lost much of their capacity to adsorb phosphorus.

Oberts found that the performance of the McCarrons system had clearly declined during the second monitoring study. The mass reduction of sediment, phosphorus and nitrogen dropped to 66, four and 33%, respectively (Table 1). Most of the pollutant removal occurred in the pond rather than the wetland, with the exception of nitrogen. Pollutant removal during storm events at McCarrons was generally within the range of pollutant removal for other pond and wetland systems (Table 2). Removal during snowmelt events was slightly lower. Pollutant removal was greatest during the onset of snowmelt, but declined sharply and even became negative during the later stages of the melt.

Table 1: Total Mass Removal Efficiency of the McCarrons Pond/Wetland System (Storm and Base Flow)

Parameter	1985 - 1986 Study (%)	1995-1996 Study (%)
Total suspended solids	96	66
Volatile suspended solids	95	56
Total phosphorus	70	4
Dissolved phosphorus	45	23
Chemical oxygen demand	80	32
TKN	55	19
Nitrate	63	68
Total nitrogen	58	33
Lead	93.2	not measured
Zinc	not measured	38

The primary factor causing the decline in pollutant removal rates from 1985 to 1995 was the fact that the system became "leakier" in between storm events. This behavior is best exemplified by the export of total phosphorus under baseflow conditions (Figure 2). In 1985, total phosphorus removal was consistently high during storms but was essentially zero during baseflow conditions. While storm removal remained fairly high during the 1995 study, a substantial mass of total phosphorus was exported during baseflow conditions (total phosphorus removal was an astounding negative 344 percent). The baseflow total phosphorus concentration out of the system doubled from 1985 to 1995, and was actually higher than the average concentration leaving the system during storms (Table 3).

Oberts also measured the delta-T or change in stormwater and baseflow temperature as it flowed through the system. He found that the system increased the average flow temperature by nine degrees Fahrenheit during the productive summer months. Interestingly, the warm discharge from the system had a strong influence on the limnology of Lake McCarrons. The warmer stormwater flows did not mix through the water column, but instead remained in the epilimnion, or upper part of the lake. Since the stormwater phosphorus concentrations were high, this led to higher algal growth in the lake than would have otherwise occurred.

Table 2: Comparison of Pollutant Removal During Rainfall and Snowmelt Events, Lake McCarrons 1996-1996

Parameter	Storm event removal (%)	Snowmelt event removal (%)
Total suspended solids	78	76
Total phosphorus	38	35
Dissolved phosphorus	52	36
Chemical oxygen demand	48	42
TKN	39	26
Nitrate-N	60	48
Total nitrogen	42	29

Another stormwater practice that has been sampled at two separate points in time was located in a much warmer climate—a Florida pond/wetland system originally monitored by Martin and Smoot (1986) and subsequently monitored about seven years later by Gain (1996). This retrospective study also concluded that sediment and nutrient removal declined sharply as the system aged, and in many cases, became negative (Table 4). It should be noted that Gain's retrospective analysis was plagued by problems that make it hard to make an exact

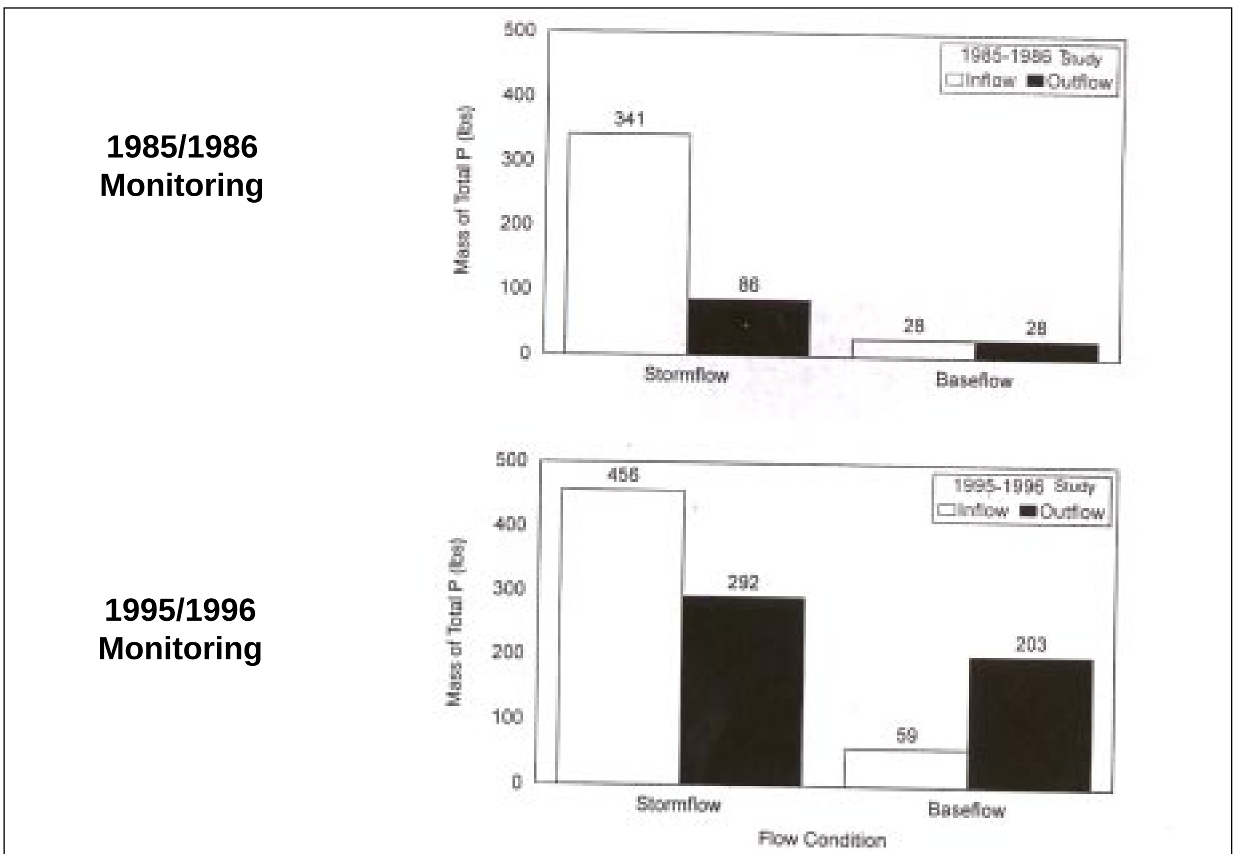

Figure 2: Phosphorus Mass Balance in the McCarrons System: Baseflow and Stormflow

Table 3: Mean Outflow Concentrations (mg/l) From the McCarrons Pond/Wetland System, 1995 and 1996

Parameter	Stormflow	Baseflow	
Total suspended solids	22.6	14.0	(10.0)
Total phosphorus	0.25	0.32	(0.16)
Dissolved phosphorus	0.13	0.08	(0.06)
TKN	1.42	1.47	(1.23)
Nitrate	0.27	0.21	(0.31)
Total nitrogen	1.64	1.68	(1.54)
Zinc	0.009	< 0.009	

Note: Numbers in parentheses reflect baseflow means for the 1985-1986 monitoring study for comparison purposes

Table 4: Comparison of Storm Pollutant Removal at a Florida Pond/ Wetland System Seven Years Apart (N=22) (Gain, 1996)

Parameter	1982 - 1984 %	1989 - 1990 %
Total suspended solids	55	24
Total organic carbon	5	-31
Total phosphorus	22	-9
Dissolved phosphorus	34	5
Total nitrogen	15	-25
Total lead	74	23
Total zinc	39	45

comparison (e.g., the runoff coefficient increased over time, the pond had filled with at least a foot of sediment, incoming pollutant concentrations had declined and often were near the irreducible levels, and storm frequencies were different). Still, the performance trend at the Florida pond was clear. The modest reduction in nutrient loads was offset by a modest export from the wetland. Some evidence was found for internal nutrient recycling within the both the pond and wetland.

Summary

The return to Lake McCarrons suggests that the pollutant removal performance of pond/wetlands may not hold up over time, especially for wetlands, and particularly for phosphorus. While the removal rates for the pond component also declined, the drop was not nearly as great as the wetland. Many more carefully controlled retrospective studies are needed at other ponds and wetlands before this finding can be generalized. But in the meantime, prudent watershed managers should reevaluate their assumption that the long term pollutant removal of stormwater practices is constant, and possibly consider "discounting" removal rates when formulating watershed plans or TMDLs.

The study of the Lake McCarrons system is not over. In the next few years, the wetland will be extensively "repaired," possibly by reconfiguring the wetland berms, removal or burial of saturated soils, regrading of wetland swales to reduce channelization and installation of a new inlet structure from the pond to the wetland. Oberts plans a third monitoring effort to test whether the wetland repair will actually improve pollutant removal rates for the system.

—***TRS***

References

Gain, W.S. 1996. "The Effects of Flow Path Modification on Water Quality Constituent Retention in an Urban Stormwater Detention Pond and Wetland System. Orlando, FL." *US Geological Survey Water Resources Investigations Report 95-4297*. Tallahassee, FL .44 pp.

Martin, E. and J. Smoot. 1986. "Constituent Load Changes in Urban Stormwater Runoff Routed Through a Detention Pond/Wetlands System in Central Florida." *US Geological Survey Water Resources Investigations Report 85-4310. 74 pp*.

Oberts, G. 1997. *Lake McCarrons Wetland Treatment System -- Phase III Study Report*. Metropolitan Council Environmental Services. St. Paul, Minnesota

Oberts, G.L and R.A. Osgood. 1988. *Lake McCarrons Wetland Treatment System: Final Report on the Function of the Wetland Treatment System and the Impacts on Lake McCarrons*. Metropolitan Council Publication no. 590-88-095. St. Paul, MN.