Arboretum Leaflets
Restoration Discovery Research

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How ponded runoff and invasive cattails reduced wetland ecosystem services in three experimental wetlands

It is rare—but essential—for ecologists, hydrologists, and engineers to collaborate in restoring wetlands so they can support native vegetation and manage urban runoff[3,6-9]. Thus, expectations were high when six UW researchers from ecology, hydrology, and bioengineering were funded to improve stormwater treatment at the Arboretum. Their three-year interdisciplinary study showed how wetland ecosystem services responded to varied hydrological regimes. Not only did the research advance ecosystem science, it also identified ways to improve stormwater facility designs and management.

Key findings and ▶ advice were that:

Subsoils that were expected to perform uniformly were in fact heterogeneous, with higher permeability in Swales I and II, which infiltrated enough water for topsoil to dry between rainfall events (Fig. 2), and a thicker clay layer in Swale III, which continuously ponded water.

▶ **Advice: Anticipate substrate heterogeneity in glacially-complex substrates, and develop plans that can accommodate conditions ranging from well-drained to ponded.**

Background: Four parallel wetlands (@90 m long x 4.7 m wide x 0.3 m deep; slope: 0.06 cm m^{-1}) were excavated in 2008-9 to create replicate swales for experimental treatment of runoff from a 58-ha urban watershed (Fig. 1). Each swale had its own V-weirs; upstream weirs were set for identical inflow of water from the 0.12-ha stormwater forebay and pond (Fig. 1). Local topsoil (28:59:13 sand:silt:clay; 0.13-0.20% nitrogen) was stockpiled during construction, then added to each swale to a depth of 15 cm (although opposed by researchers). Soil cores (to ~15 cm depth) taken in Nov. 2010 averaged ~3% organic matter with ~44-54 mg phosphorus kg-soil^{-1}) (Prellwitz 2013). Contractors seeded swales with 27 native wetland species in Nov. 2009, but few seedlings established in 2010 (seed-bank study by Boehm 2011) or thereafter. The westernmost swale had unique plantings and was not compared for ecosystem services. During 2010, the site received enough rainfall for water to pond and abundant cattail seedlings to invade the wettest areas. Stormwater was shunted into the swales in 2011 after the vegetation was judged "thick" (a performance criterion). However, all weirs leaked, so flows were again diverted. As soon as weirs were retrofitted, researchers assessed water quality services (Sept. 2011 through October 2012).

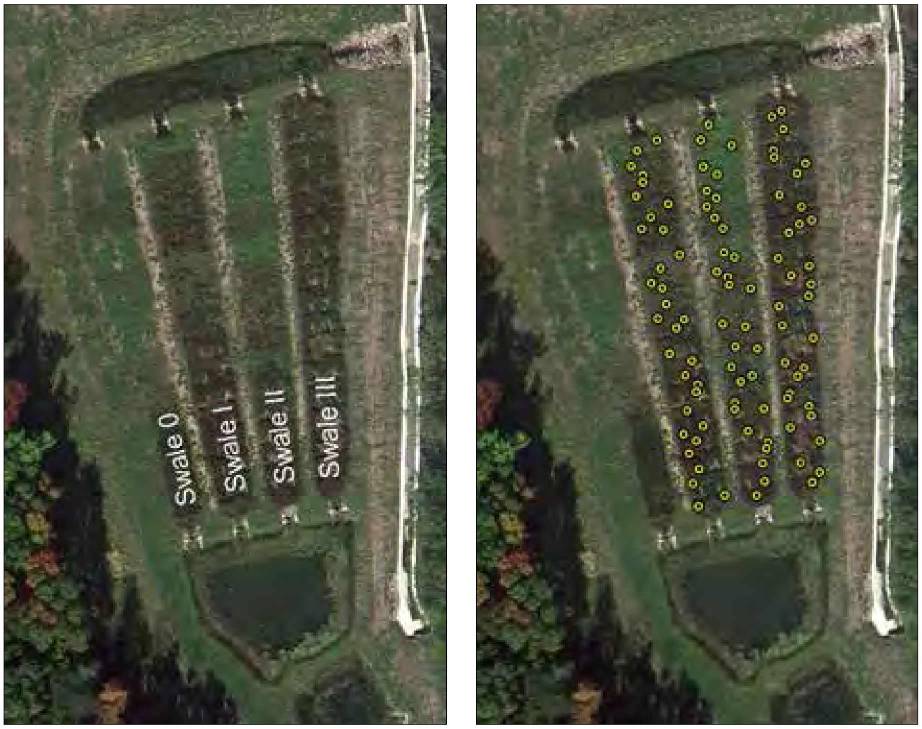

Figure 1. Swales just east of Curtis Prairie at the UW-Madison Arboretum. Aerial photo of experimental wetlands (Swales I-III used herein); on right: 104 plots sampled for vegetation, each 0.25 m^2 in area. Plots mapped by Doherty based on aerial photos made available by Mark Wegener.

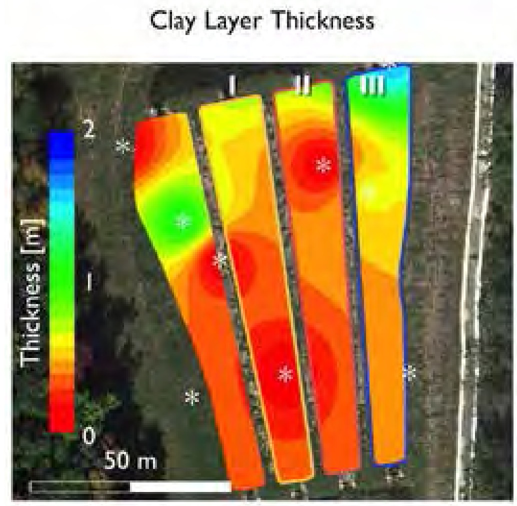

Figure 2. Clay was thickest in swale III, which held the most surface water. Mapped estimates based on only 9 soil borings. Imagery by J. F. Miller.

Cattails invaded each wetland in relation to hydroperiod duration (Swales III>I>II)—more ponding, more cattails (Fig. 3). With greater cattail dominance, there were fewer plant species (9<19<29 spp.). Few of the 27 seeded native species established, despite costly efforts.

Advice: Expect weedy monocultures in wet, nutrient-rich sites. Test all seed for viability before sowing.

Figure 3. View of the wettest swale (III), dominated by cattails, in August 2011. Drier swales are in the distance. Photo by Zedler.

Figure 4. Prellwitz used a cohesive-strength meter to assess erosion resistance. Photo of Prellwitz by Z. Zopp.

Mosses and algae were scarce under the high biomass and thick litter of invasive cattails, and the soil surface was unstable and vulnerable to erosion. Moss mats under species-rich, low-shade vegetation resisted up to 60 pounds per square inch of water pressure (Fig. 5).

Figure 5. Mats of moss (left) and algae (right) stabilized sediments where vascular plants were sparse and light reached the soil surface. Photos by Prellwitz.

- **More nutrients flowed out of the swales than flowed in (Fig. 6). Although designed to be "sinks," all three wetlands exported phosphorus (Swale III>I>II), and the wettest swale (III) also exported nitrogen and suspended solids (Prellwitz 2013).**

- **Advice: Avoid ponding and cattail invasion in designing/managing swales for nutrient removal.**

Figure 6. Automated, solar-powered samplers being inspected by Raj Patel, EPA Project Supervisor, during his August 2011 site visit. In- and out-flowing water was sampled and stored; each carousel rotated to accept sequential samples. Runoff from 13 storms (late 2011 through 2012) was analyzed water to assess removal of Total Phosphorus, Total Dissolved Phosphorus, Total Nitrogen, and Total Suspended Solids (TSS). Photo on left by Zedler; photo of auto-sampler by Prellwitz.

Figure 7. Swales differed in hydroperiod and vegetation. Left photo of Zopp in Swale I shows short-statured vegetation. Right photo of Doherty in Swale III shows taller cattails. Photos by Prellwitz

- **Six ecosystem services responded to the combined effects of hydroperiod and invasive cattails (Fig. 8). Swales ranged >2-fold in aboveground biomass, >2-fold in numbers of plant species, 18-fold in stormwater retention, and >17-fold in water quality improvement. Ranges in swale flow attenuation and erosion resistance varied nearly 2-fold (1.6x and 1.8x, respectively).**

- **Where infiltration shortened hydroperiods (especially Swale II), five services attained their highest levels: support of plant diversity, erosion control, water quality improvement, flow reduction, and stormwater retention.**

- **Contrary to assumptions, net primary productivity [NPP] was negatively correlated with 5 other ecosystem services: The wettest swale (III) had the highest NPP but provided the lowest levels of all other services assessed.**

- ▶ **Advice: Manage treatment wetlands for their ecosystem services, not just their appearance. A visual judgment of "thick vegetation" does not indicate the capacity of a wetland to treat stormwater.**

Figure 8. Differential wetland ecosystem services (label at top of map), depicted relative to the most of each service performed by any swale. Large stars indicate that a swale provides the most of that service (e.g., Swale III provided the most NPP); smaller stars indicate lesser service, dots indicate very low service, and no symbol indicates barely-measurable service by that swale..

- ▶ **Advice: Vascular plant cover, leaf area, and biomass should not be considered proxies for five ecosystem services: stormwater retention, peak-flow attenuation, soil stabilization, nutrient removal, or diversity support. On the contrary, dense cattail litter indicated erodible muck and potential for nutrient export.**

OVERALL MESSAGE: Assessments of wetland services in general—and stormwater treatment facilities in particular—need to become more science-based. Interdisciplinary research can reveal complex hydrological, ecological, and physico-chemical linkages among wetland functions.

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