Floating treatment wetlands improve stormwater quality

By Mark Reinsel

Floating treatment wetlands (FTWs) have significantly reduced nutrient and solids levels in stormwater ponds and have been approved as stormwater best management practices (BMPs) in several jurisdictions.

They have been shown to enhance contaminant removal in stormwater ponds in studies by Floating Island International (FII) and other researchers, and users are now given a numeric credit for their removal. FTWs can significantly improve runoff water quality and reduce its environmental impact.

BioHavens® are passive islands consisting of post-industrial polymer fibres and foam for flotation, and vegetated with native plants. BioHavens and natural floating islands are essentially biofilm reactors with plants. Plant roots hang beneath the floating island and provide a large surface area for biofilm growth, which forms an important part of the treatment reactor.

Studies have shown that approximately 80% of an island's nutrient cycling ability comes from biofilms, while plants, although they are the most visible component of an island, are responsible for only about 20%.

Case study: North Carolina

An independent research project conducted for the North Carolina Department of Environment and Natural Resources (NCDENR) directly compared contaminant removal from ponds with and without FTWs. The BioHaven FTWs used in this study mimic and enhance the ability of natural wetlands to clean water by bringing a "concentrated wetland effect" to stormwater ponds. FTWs are an attractive retrofit to "wet ponds" (those that permanently contain water) because they:

- Do not require earthmoving.
- Eliminate the need for additional land to be dedicated to treatment.
- Float, so they will not add to the storage volume required for wet ponds.
- Allow for a smaller detention basin/wet pond BMP footprint.
- Increase plant survivability, which is expected to increase treatment efficacy.
- Allow for more detention within a pond that has been modified to draw down its level between rain events. Being able to do this will allow pond owners to meet volume reduction goals that are becoming the regulatory norm.

Figure 1. DOT pond with mature FTWs (photo by Rob Crook, FISE)

To test whether FTWs provide a benefit for nutrient and total suspended solids (TSS) removal, two ponds in Durham, North Carolina, were monitored, pre- and post-FTW installation. The first, the DOT pond had 9% of its surface area covered, while the second, the Museum pond, had 18% coverage. At least 16 storm events were sampled from each pond in each period.

FTWs improved performance of both ponds, with the Museum pond having statistically significant improvement for both total phosphorus (TP) and TSS. Fraction of coverage appears to be an important variable. Root length was approximately two feet below the pond surface, which has the benefit of reducing water velocity and increasing sedimentation.

A very small fraction of N and P was also taken up by the plants. Mean effluent concentrations of total nitrogen (TN) were reduced at one pond from 1.05 mg/L to 0.61 mg/L. Mean TP effluent concentrations were reduced at both ponds (0.17 mg/L to 0.12 mg/L at the DOT pond, 0.11 mg/L to 0.05 mg/L at the Museum pond). Post-retrofit concentrations are similar to those observed for bioretention cells in other studies.

Importantly, both the pre- and post-FTW retrofit ponds performed well from a pollutant removal perspective. The Museum pond had extremely low TN effluent concentrations (0.41 mg/L and 0.43 mg/L) during the pre- and post-FTW retrofit periods, respectively. Both ponds regularly exceeded the assigned NCDENR pollutant removal credits for TN, TP and TSS, as hoped. The final project report recommended offering additional credits, when FTWs are incorporated at various levels.

Removal results for the DOT pond (large pond, 9% coverage) for nitrate, TN, TP and TSS are shown in Figure 2 for pre-FTW and post-FTW conditions. Removal improved with FTWs for all parameters except TSS. This was likely due

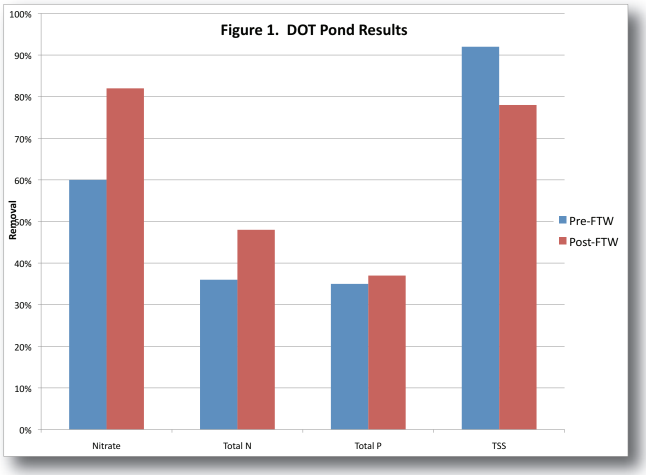

Figure 2. DOT pond results.

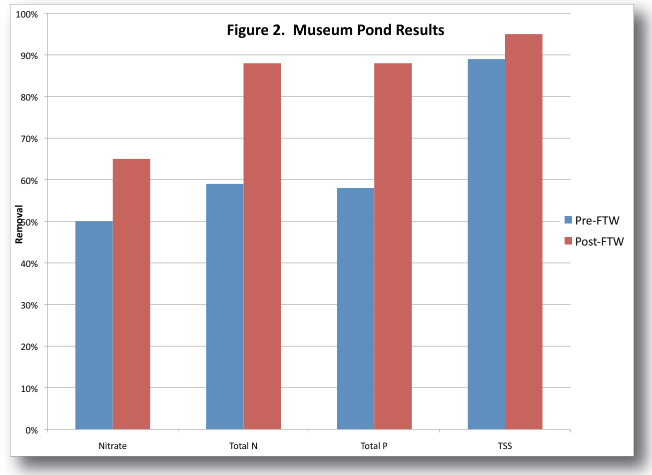

Figure 3. Museum pond results.

to factors other than the FTW. Removal results for the Museum pond (small pond, 18% coverage) are shown in Figure 3. With higher coverage, removal with FTWs was much higher for all parameters except nitrate. FTWs improved removal of TP and TSS to a statistically significant degree.

Case study: Montana

In November 2008, the City of Billings, Montana, constructed a pond to treat a portion of stormwater discharging from Metra Park, a 174-acre drainage area dominated by light industrial and commercial properties. A large BioHaven FTW was installed in the Metra pond shortly after its construction, along with a smaller FTW in the preceding channel.

The FTW was installed in late 2008 and planted with native grasses and other vegetation in early 2009. This vegetation became established in 2009 and 2010. Billings has an arid climate, so stormwater flow occurs infrequently. Three samples taken in 2009 showed little removal of the eight contaminants measured. However, two samples taken in late 2010 and early 2011, after the FTW vegetation had matured, showed dramatic contami-

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Figure 4. Metra stormwater pond with FTW, June 2011 (photo by FII)

nant reductions between the stormwater pond inlet and outlet.

The FTW installed in the Metra Park stormwater pond has very effectively removed the eight contaminants monitored. Removal percentages from the last two sampling events range from 63% to 98%. The FTW's effectiveness substantially improved after its vegetation had matured for two growing seasons. The extended root system likely provided more surface area for TSS removal and biofilm growth. The large jump in treatment effectiveness from the first year of operation shows the effect of the FTW, compared to the pond by itself.

Stormwater treatment review

An extensive literature review of FTW effectiveness in treating stormwater was published by Headley and Tanner in 2012. Their conclusion was that FTWs offer potential advantages for treating highly variable flow rates and concentrations encountered with stormwater. Advantages include the ability of FTWs to tolerate widely fluctuating water levels and the large surface area provided by the FTW structure and plant roots for attachment of microbial biofilm, which will perform the bulk of the contaminant reduction.

Although they note that further studies are needed to confirm the effectiveness of FTWs treating stormwater at full scale, the authors provide data from mesocosm (experimental water enclosure) and pilot studies showing substantial removal of organics, suspended solids, nutrients and metals

Similar to the NCDENR study, a controlled experiment in New Zealand examined the effect of retrofitting an FTW to a stormwater pond. The study differed from the one in North Carolina in that two parallel ponds were studied (one with an FTW and one without), rather than comparing data from the same pond before and after FTW installation.

It showed that the FTW pond removed 41% more TSS than the "control" pond, with 40% higher removal of particulate zinc and 39% higher removal of particulate copper. All these differences were statistically significant. Metal particulate removal is likely associated with TSS removal.

Best management practice status

In Florida, FTWs that cover more than 5% of the surface area of a wet pond now receive an additional 12% "credit" for TN and TP reduction. This means wet ponds receive an additional credit of 12% towards their watershed nonpoint source reduction goals.

In June 2013, FTWs will be formally recognized by NCDENR as an approved BMP. The North Carolina numbers are not official until the announcement is made. However, Floating Island International anticipates that adding a BioHaven, covering less than 17% of the surface area of a wet pond, will receive an additional 5% credit for TN and TP reduction. Wet ponds with BioHavens that cover more than 17% surface area will earn an additional 10% credit. These credits are in addition to the 25% credit that properly constructed wet ponds currently earn in North Carolina.

In 2011, the Chesapeake Bay Program's Urban Stormwater Workgroup initiated four independent research efforts with leading universities to assess FTWs as a watershed water quality management tool. At the workgroup's July 2012 session, research results were presented and the group recognized FTWs as an approved BMP. A subgroup was formed to assign rates or credits later in 2013.

Most recently, the City of Philadelphia recognized FTWs as an approved BMP and added FTWs to its best management practice website.

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Contaminant	Average concentration (mg/L) Inlet	Outlet	Average removal
Total suspended solids (TSS)	391	28	93%
Chemical oxygen demand (COD)	256	30	88%
Total phosphorus (TP)	0.81	0.099	88%
Total nitrogen (TN)	3.14	0.867	72%
Copper	0.091	0.009	90%
Lead	0.085	0.004	95%
Zinc	0.875	0.056	94%
Oil & grease (O&G)	7.1	1.2	83%

Table 1 – Target flows and field operating conditions.

Parameter	Removal rate Areal (g/m2/day)	Volume (g/m3/day)
BOD	7.3	16.9
Ammonia-N	1.0	3.1
Total N	1.3	3.7
Total P	0.3	0.9

Table 2. Average removal rates for FTWs