Fremont Tree Well Filters | LID Performance on a Redeveloped Urban Roadway

Site Summary	Project Features	Subsurface-Loaded	Surface-Loaded
The Fremont Low Impact Development Tree Well Filter pilot project retrofitted a moderate density urban feeder street with green stormwater infrastructure to improve city aesthetics and treat urban runoff to remove PCBs, mercury, copper and trash as mandated in the Municipal Regional Stormwater NPDES Permit (MRP). Two tree well filter designs were trialed: one that receives stormwater at the surface of the tree well (surface-loaded), and the other is a City of Fremont-designed subsurface-loaded filter system that receives runoff one foot below the surface. The tree wells were monitored over a series of storms to evaluate their effectiveness at reducing pollutant concentrations.	**Year Constructed**	2011	
	GI Elements	Subsurface and Surface loaded Tree Well Filter bioretention systems	
	Drainage Management Area (ft^2)	8,880	8,650
	% of Impervious Area Converted to GI	4%	4%
	Monitoring Period	2011/12 visual observation; 2012/13 and 2013/14 winter season stormwater quality monitoring	
	Land Use(s)	Minor arterial road; office buildings and light industrial properties	
	Parameters/Analytes Measured	Rainfall, turbidity, conductivity, SSC, total and dissolved Hg, total MeHg, total and dissolved Cu, PCBs, total nitrogen, nitrate, total phosphorous, dissolved orthophosphate and ammonia	

Figure 1. A) Subsurface-loaded tree well filter, B) surface-loaded tree well filter, and C) regional aerial of southeast and South San Francisco Bay showing location of tree well filters in the urban Fremont area.

Highlights:

- **The tree well filters (TWFs) likely meet the flow and volume reduction targets.**
- **The TWFs reduced the concentrations of a range of pollutants but some nutrients appeared to be sourced from the TWFs.**
- **The magnitude of water quality performance is dependent upon influent concentrations; the use of LID for improving water quality in relatively clean landscapes will likely yield lower performance.**

Project Overview

NPDES permits require mitigation for creating or replacing 10,000 ft^2 or more of impervious surface area. Based on this requirement, the City of Fremont constructed side-by-side tree well filters (TWFs) along a moderate traffic density minor arterial road (Figures 1 and 2). One of the TWFs is a traditional design in which stormwater runoff enters at the surface of the unit (surface-loaded) ponds on the surface and infiltrates through the media. The City also developed a TWF system that integrates the requirements for full-size street trees and stormwater treatment into one device. This City-designed TWF has a unique, subsurface-loaded design in which stormwater is introduced into the treatment measure via an underground distribution pipe. The two TWFs were monitored simultaneously during the winter seasons of water years (WYs) 2013 and 2014 to evaluate and compare their performance reducing pollutants to the San Francisco Bay.

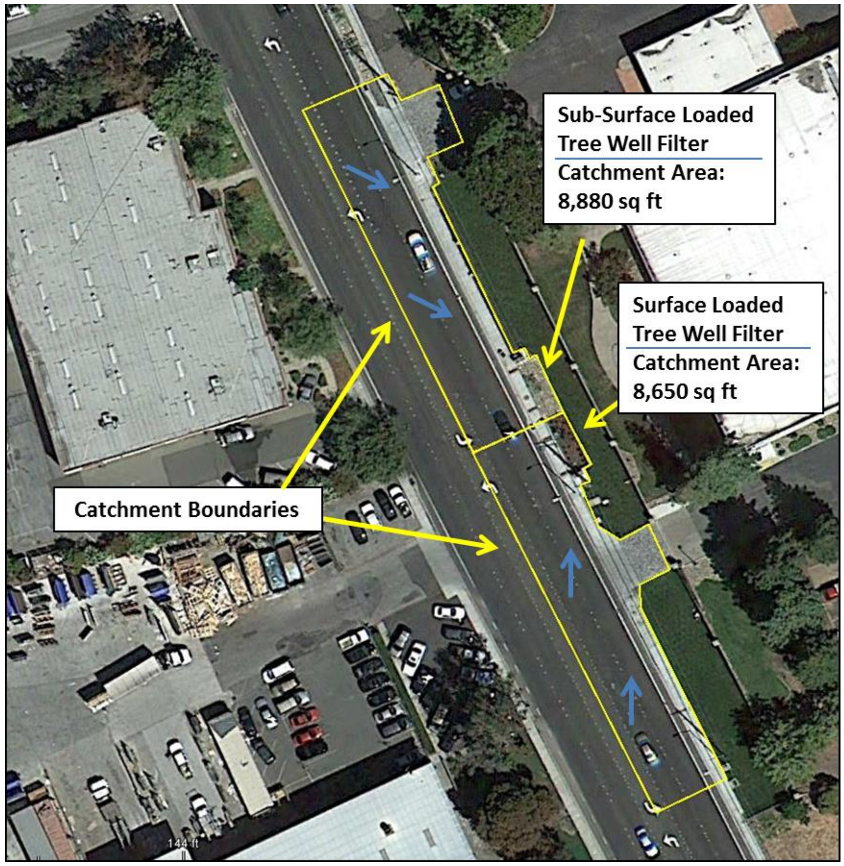


Figure 2. Aerial photograph of Fremont tree wells and catchment boundaries. Area that drains to each TWF is outlined in yellow.

Figure 3. Inlet and outlet monitoring in the surface-loaded tree well (A) and outlet monitoring at the subsurface-loaded tree well (B) during a storm event.

Inlet – Outlet Storm Monitoring

The primary goals of this study were to: 1) qualitatively assess whether the TWFs were treating the permit-required volumes and flows (80% of the stormwater runoff volume or flow rates up to 0.2 inches/hr), and 2) measure the percent reduction in pollutant concentrations in each TWF. The effectiveness of each TWF was directly measured during five storm events via collection of discrete grab samples at the inlet and the outlet from each TWF (Figure 3). Data from the first storm season suggested no statistical difference between influent concentrations to each TWF; an observation that is consistent with the similarities of land use across the two catchment areas. Therefore, inlet monitoring was simplified to a single point of collection to increase cost effectiveness of the monitoring design. The outlets to each TWF continued to be sampled separately in order to compare differences in their effectiveness. Sampling occurred during two relatively dry rainfall years. The five monitored storms ranged in duration from 4 to 24 hours and included total rainfall depths ranging between 0.15 and 2.32 inches. Storms with these characteristics are relatively common in Fremont.

Project Findings

Do the TWFs meet the flow and volume-based permit requirements?

The Fremont TWFs were designed to meet the MRP C.3.d. permit sizing requirements for the combination of flow and volume basis, and based on qualitative observations, it is likely they do so. The MRP requires that at least 80% of the total stormwater runoff is treated, or minimally, flows with an influent rate of 0.2 inches per hour are treated. This study qualitatively assessed whether these requirements were met. Rainfall intensities varied between maximum rates of 0.21 inches per hour and 0.72 inches per hour. The TWFs captured 100% of the runoff during the two storm events with rainfall rates of 0.21 inches per hour, whereas episodic bypass was observed during three of the four events with rates greater than 0.32 inches per hour. Based on these observations, it is likely the TWFs treat rainfall rates up to 0.2 inches per hour.

Similarly, using the observational data coupled with rainfall intensities and estimated total runoff and total bypass (stormwater that passes by the TWF inlet and goes directly into the storm drain) for each storm, our best professional estimate of total bypass is approximately 15-20% of the total annual volume (Figure 4).

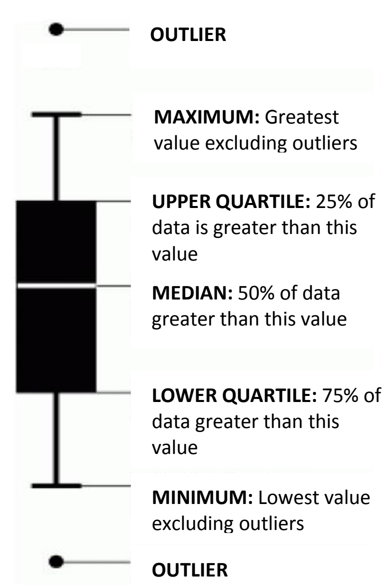
Figure 4. Stormwater bypassing the subsurface-loaded TWF inlets and flowing directly into the storm drain via the adjacent drop inlet

Were Pollutant Concentrations Reduced?

In typical urban areas during storm events, stormwater runoff transports pollutants into storm drains. The TWFs are designed to filter the stormwater before entering the stormdrain, thereby reducing the pollutant concentrations and loads that flow into the stormdrain system and out to San Francisco Bay. The reduction in pollutant concentrations between the inlet and outlet to each TWF serves as one straightforward and important measure of effectiveness at reducing pollutant loads.

The two Fremont TWFs had mixed performance results on pollutants measured in the study (see Figure 5 for summary of pollutant sample concentrations for the entire study; call-out box at right is a key for reading the boxplots). Suspended sediment concentration, methylmercury and dissolved ammonia all showed significant decreases at the TWF outlets. Given the relatively "clean watershed" in relation to sources, the TWFs appear to be ineffective at significantly reducing PCBs, copper species and TKN, and effluent exiting the TWFs is generally higher in dissolved mercury as well as nutrients. Nutrients may be sourced from the TWF filtration media or, in the case of nitrate plus nitrite, through nitrification processes occurring in the TWF media. Some significant differences in performance between the two TWFs existed, namely, the subsurface-loaded TWF exported significantly lower dissolved and methylmercury concentrations, while the surface-loaded TWF exported significantly lower concentrations of some nutrients. The cause of these differences may include differences in influent concentrations, differences in the soil/compost composition within the TWF, or differences in nutrient uptake processes and pollutant species conversions in the anaerobic soils.

Reading a Box-and-Whisker Plot



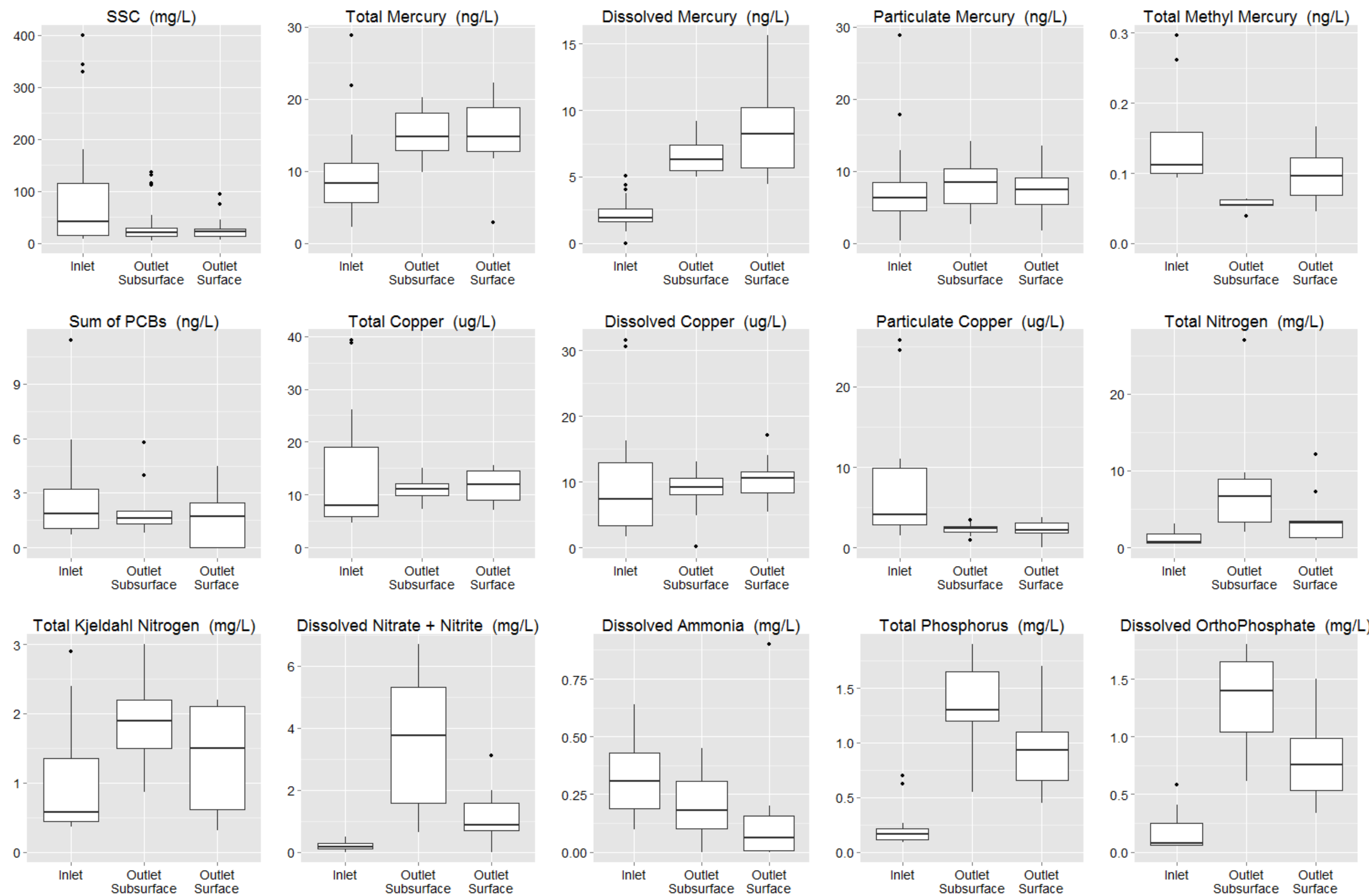


Figure 5. Distributions of concentrations measured throughout the study at the inlet (data from both tree well filters combined) and each TWF outlet. Note: see call-out box on previous page for details on how to read a box-and-whisker plot.

Why weren't concentrations reduced, or reduced more?

LID does not always result in water quality improvements for all pollutants. It has been shown that several factors affect whether concentrations are reduced between the inlet and outlet, and many scientists and engineers have questioned whether comparing concentrations between the inlet and outlet is even the right metric for evaluating performance of an LID project. Those several factors include the concentrations at the inlet (what levels of pollutants are in the runoff), the specific pollutant and its source characteristics (pollutant characteristics can influence treatment processes), and the type of LID (a TWF may perform better on certain pollutants than other LID treatments), in addition to other characteristics such as design specifications and maintenance challenges such as trash and leaf debris. Performance criteria for assessing LID projects are still developing.

Locally, we are starting to develop performance curves which show the connection between pollution levels in the stormwater runoff entering the LID feature, and the degree of pollutant reductions as a result of the LID. These performance curves (Figure 6) are based on local Bay Area LID project data, though the trends illustrated locally are generally also supported in the national and international LID literature. The performance curves illustrate that greater reductions are gained in more polluted areas. The Fremont TWFs are located in a relatively unpolluted area, and therefore performance is limited. The TWFs may perform better if greater concentrations of pollutants were passing through them.

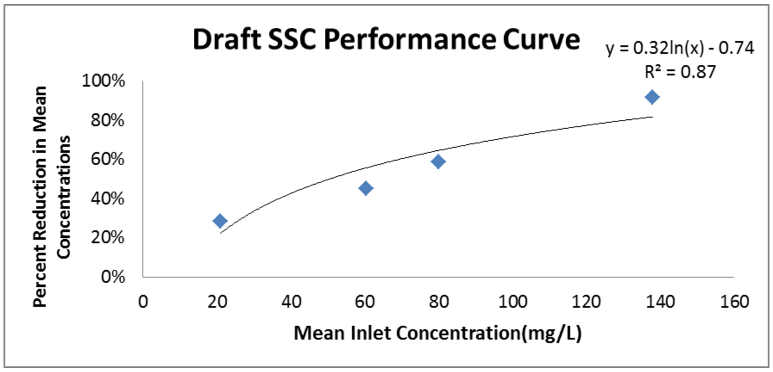


Figure 6. Draft performance curve for suspended sediment based on findings from three Bay Area bioretention studies.

Lessons Learned

The results of this study highlight that while TWFs/LID features placed in highly polluted watersheds may have high performance, lower performance can be expected from TWFs/LID in relatively "clean" watersheds. Soil media specifications are currently controlled by regional regulation, but since some nutrients can be sourced from soil media, thoughtful consideration should be applied in the planning and design of LID in "clean" watersheds. When and where it is possible, low-nutrient media should be used, and soil media that promotes sedimentation, filtration, and properties that can retain pollutants of concern should be considered. When water quality improvement is a goal for implementing LID, consideration should be given to placement of these features with respect to pollutants in the landscape.