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A Wet Pond as a Storm Water Runoff BMP – Case Study

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ABSTRACT

The California Department of Transportation (Caltrans) has initiated a five-year study in San Diego to examine the benefits, technical feasibility, costs, and operation and maintenance requirements of using a wet pond to treat storm water runoff from an existing freeway. The purpose of this program is to study the opportunities and constraints, relative to siting, design, construction, operation and maintenance, associated with retrofitting highways with this type of stormwater Best Management Practice (BMP) and to evaluate the efficiency of the device for removing pollutants of concern. Automated monitoring stations have been installed at the site upstream and downstream of the BMP. Constituents monitored in the runoff include: suspended solids (e.g., sediment), metals, nutrients, and organics (e.g., gasoline). Vectors (i.e., mosquitoes), vegetation, and protected and endangered species are also being monitored. A comprehensive operation and maintenance program is in place to ensure the BMP operates at peak performance. Construction and maintenance costs are being documented. Over the past three years, the project has been sited, designed, constructed and monitored (for the first year). Even though pollution-removal data are not yet available, Caltrans' experience indicates that there are substantial challenges in retrofitting wet pond BMP technology into transportation infrastructure.

INTRODUCTION

A wet pond is being tested as part of the Caltrans Best Management Practice (BMP) Retrofit Pilot Studies, which is also testing 11 other types of structural BMPs (i.e., treatment devices) at 38 different installations. The pond is located in the southeast corner of the intersection of La Costa Ave. and I-5 in San Diego County. It is currently in its first year of operation. Five aspects of this wet pond case study are discussed here — siting, design, construction, operations and maintenance, and efficiency evaluation. Constraints, problems, and solutions of the siting, design, and construction are presented along with the and the study design for the operation, maintenance, and efficiency evaluations.

The wet pond has a permanent pool of water that is fed by a nearby urban dry-weather flow. The pond is designed with additional storage capacity to capture storm water runoff from the 1 year, 24-hour event, which is diverted to the pond from the nearby freeway. During a rainfall event, storm water flows into the pond, where it inundates the surrounding vegetation. Vegetation in and around the basin provide for enhanced solids removal. The vegetation also provides a structure for an active microbial community that is expected to improve the uptake of dissolved pollutants. The comingled water is discharged until the water level returns to the level of the permanent pool. The permanent pool is divided into two sections by a gabion wall. The forebay is to concentrate sediment capture in one area for ease of maintenance, and allows less intrusive maintenance for the main pool. An impermeable lining is buried at below the invert of the wet pond to maintain the permanent pool of water and circulation by minimizing infiltration losses. An emergency spillway is incorporated into the design for high flow conditions.

PROJECT SITING

The site selection process began with a reconnaissance of Caltrans highways and freeways in San Diego County. Site evaluations included an initial feasibility investigation, followed by a more detailed site investigation.

A feasibility investigation was performed to determine the locations of surplus areas owned by Caltrans along freeway and highway interchanges, and on- and off-ramps. The feasibility investigation started by reviewing topographic maps to ensure that identified sites were located at or near the low point of the associated highway drainage. Candidate sites from the feasibility phase were further investigated to determine available site area, estimated tributary watershed and the availability of a perennial water source for the permanent pool. Adequacy of the site was determined by estimating the required basin surface area (a function of tributary area, 0.5 percent was used), including safety setback limits required by Caltrans. If these criteria were satisfied, further site investigation was completed, such as reviews of geotechnical conditions and Caltrans grading and drainage plans. Safety concerns dictated several siting criteria, including the reservation of a 9.1 m (30-foot) clear recovery zone (for motorist safety) around the perimeter of the basin. In addition, the basin must be protected by guardrail behind the edge of shoulder.

Finally, the site information was evaluated using a weighted decision matrix. Each site was evaluated and compared with respect to several different criteria. The criteria were weighted according to their importance and relevance to the site selection process. The most important criteria were:

- sufficient area (without substantial improvement);
- location away from building foundations and highway pavement;
- proximity to receiving waters;
- ease of maintenance access;
- availability of a perennial water source.

Each site scored 1 to 10 with respect to each criterion. The site's total score was the sum of the individual scores, multiplied by the weighting factors associated with that criterion.

BMP DESIGN

The design storm used for the wet pond is the estimated 1-year, 24-hour storm event. At the La Costa Ave. site in San Diego, this rainfall is calculated to be 3.40 cm (1.34 in.). The computed time of concentration for the site is 22.3 minutes for the 1.7 ha (4.2 acre) tributary watershed.

The basin side slope ratio varies between 1:3 and 1:6. The design residence time is 24-hours for the 1-year storm frequency. The average permanent pool depth is 0.7 m (2.3 feet). The water quality pool depth is 0.19 m (0.63 feet) with a volume of 777 m^3 (0.63 acre-feet).

The ratio for permanent pool to the water quality capture volume is 3:1 per the following relationship (Young, 1996):

$$\mathbf{VPP = 3 \times (V_{WQ})}$$

where: V_{PP} = permanent pool volume

V_{WQ} = 1-yr, 24-hr water quality capture volume

The outlet structure controls the discharge rate by way of an orifice to achieve the desired detention time. An overflow weir at the outlet structure is designed to pass larger, but less frequent, discharges. A spillway discharges storm events significantly greater than the 1-yr design volume; however, the basin is designed as an off-line device, thus limiting surcharge flows. Runoff volumes up to the design storm are directed to the basin; discharge volumes in excess of the 1-yr, 24-hr storm bypass the facility through the existing storm drain system.

PROJECT CONSTRUCTION

The construction of the wet pond was awarded to the low bidder, according to an accelerated Caltrans plans, specifications and estimates (PS&E) delivery process. Seven bids were submitted, and the contract was awarded to the second low bidder for an amount of $602,158, 7% under the engineer's estimate of $648,810. (The low bid was withdrawn prior to award.) The entire process from contract advertisement to start of construction took 24 calendar days.

Construction for the site began on April 5, 1999 and was completed 45 working days later on June 25, 1999. During construction, eight Construction Change Orders (CCOs) were issued at a total cost of $50,461. The CCOs were issued for additional traffic handling, the disposal of material cleaned from the adjacent receiving channel, changes to the irrigation system and adjacent highway lighting, construction of a small retaining wall (for the maintenance road), and miscellaneous site modifications.

Vegetation for the wet basin was procured through a separate contract and shipped to the contractor as state-supplied material. The initial planting occurred between June 1 and June 25 in three different zones: 1) permanent pool perimeter, 2) zone of inundation and 3) upland area. The plant materials, which were selected by a wetland biologist, differed somewhat by zone, although species native to southern California were used throughout. Irrigation was used for plant establishment only, and was discontinued about 8 months after planting.

OPERATION AND MAINTENANCE

Operation and maintenance of the wet pond consists of vegetation management for vector control, surveying for sensitive or endangered species, periodic clean up and inspection, and vector monitoring and abatement. Each is discussed below.

Vegetation management is a balance between maintaining a dense plant cover for to enhance sedimentation and maintaining open water to enhance vector abatement. Currently, the vegetation management strategy is to minimize disturbance of the wet pond, while maintaining the efficacy of mosquito fish (*Gambusia*). When the density of plant stalks becomes too great, the fish cannot get to all of the mosquito larvae. Chemical controls also require a certain amount of open water so the chemical can penetrate to the larvae. Plant density is assessed quarterly. As of April 2000, the cattails are dominating the zone of inundation. The cattails are up to 12 feet tall and some are beginning to fall over.

Any maintenance action must be preceded by a bioassessment to determine if any sensitive or endangered species are utilizing the wet pond. Assessments at the wet pond include surveying for migrating birds during the breeding season. Sensitive or endangered species utilizing the wet pond will probably preclude maintenance necessary for vector abatement and for water treatment. Activities, such as sediment and vegetation removal, could be restricted to prevent accidental takings of sensitive species. Access to the site could also be restricted to avoid disturbing nesting birds. As a result, the bioassessments have two goals. The first is two determine the likelihood that a wet pond will attract sensitive species. A treatment device that attracts sensitive species more than a comparable alternative will not be seen as the most desirable storm water treatment technology for other locations. The second goal is to identify protected species so that maintenance crews and the U.S. Fish and Wildlife Service can be notified.

Periodic inspection and clean up include sediment removal, erosion and structural maintenance, and monthly removal of graffiti, trash, debris, and other material that could clog the outlet works. Sediment accumulation is measured monthly. Sediment is removed from the forebay when the depth of accumulated sediment exceeds 5.1 cm (2 inches), and from the main pond when the depth exceeds 10.2 cm (4 inches). Erosion control and structural repairs occur as needed. After storm events the 24-hour drawdown time to the permanent pool elevation is verified, and if the time is exceeded, further maintenance action to restore the design drawdown time is coordinated with the design engineer.

Monitoring and controlling vectors is being conducted by a team consisting of the County of San Diego Department of Public Health, the California Department of Health Services (DHS), and University of California, Riverside, Department of Entomology. San Diego County monitors the wet pond weekly for vector occurrence and treats the pond as needed. To date, the Gambusia have been sufficient to control mosquitoes. DHS collects additional information that affects vector production during bi-weekly surveys (weekly during summer months). Information such as water temperature and vegetation type is recorded in a project database. DHS will compare the vector production of the wet basin with the production of the other types of BMPs being studied in the Caltrans Retrofit Pilot Program. U.C. Riverside is conducting weekly adult mosquito surveys at the wet pond, and at a nearby sand filter and infiltration basin being operated as part of the retrofit program. The three sites are far enough apart that the mosquito capture can be compared between the sites. Both gravid (egg-laying) and host-seeking mosquitoes are collected. The results of the study will help determine the relative attractiveness of the wet pond as mosquito habitat.

EFFICIENCY EVALUATION

The efficiency of the wet pond to remove pollutants will be evaluated by comparing the load going into the pond during a storm event to the load leaving the pond. Up to eight storms over two years will be analyzed. The sampling procedures follow the protocols established for Caltrans statewide stormwater monitoring efforts (LWA, 1997). The monitoring program consists of empirical observations, flow-weighted composite samples on the stormwater influent and effluent, and samples of the baseline dry weather flows.

Empirical observations made during monitored storm events are shown in Table 1. In addition, monitoring equipment is thoroughly checked before and during each monitored storm event to ensure successful data collection.

Table 1 Empirical Monitoring Observations

Type of Observation	Items Observed
Meteorological characteristics	Present wind conditions, cloud cover, and rainfall intensity and distribution.
Hydrologic and hydraulic characteristics	Flow condition at influent and effluent, emergency overflows, facility bypass, maximum water depth, and drain time
Influent and effluent water quality appearance	Evidence of erosion, flow restriction, odor, floating material, oil, grease, color, and turbidity
Solids deposition	Where and what type of solids have accumulated in the wet pond.
Erosion observations	Location, total area affected, and depth of erosion throughout the wet pond.
Vegetation observations	Vegetation coverage and type for the side slopes and invert.
Vector observations	Occurrence of mosquitoes, blackflys, cockroaches, and rats.

Flow-weighted composite samples are collected at the influent and effluent of the wet pond. The parameters being analyzed include certain conventional pollutants (pH, specific conductance, hardness, TSS), nutrients (nitrate-N, TKN, Total-P), total and dissolved metals (copper, lead, zinc), bacteria (fecal coliform), and organics (TRPH-gas, diesel, oil). The dry weather base flow is shut off during storm events. Although the contribution of base flow less than 18.9 liters per minute (5 gpm) and the runoff from a storm event can be over 3,785 liters per minute (1000 gpm) or higher, the baseline flow is shut off to eliminate interference in determining the efficiency of the device as a storm water treatment technology.

Flow-weighted composite samples for the dry weather flow are taken monthly. The data from these samples are used to estimate pollutant concentrations in the wet pond prior to the storm event. This information is expected to be useful in interpreting the pond's performance data. All water quality data collected is reported according to the Caltrans Data Reporting Protocols (1999).

DISCUSSION

Siting a wet pond for treatment of storm water in an arid climate is challenging due to the lack of a perennial water source. Safety is also a special concern because the device incorporates a permanent pool. A setback zone and guardrail are required for highway environments.

Finding sufficient site area for this kind of facility may be difficult. The pond in this project has an area of 0.25 ha (0.62 acres) to serve a tributary area of only 1.7 ha (4.2 acres). Sizing in this case was based on Caltrans' 1-year, 24-hour storm event.

There are several good references offering guidance for designing pond facilities. For sites with a relatively small tributary area, the outlet orifice must be relatively small to achieve the desired residence time. At this site, the outlet orifice is 7.62 cm (3 inches). No clogging problems have arisen to date. A smaller orifice may, however, require more maintenance.

It is imperative to include a plant establishment period in the construction contract to ensure that the plant stock is healthy and has a good survival rate. The plant material for this project required some replacement due to either poor quality of material from the nursery, or improper planting procedures during installation.

Operation and maintenance procedures for a wet pond are greatly affected by vector control needs and the possible occurrence of sensitive or endangered species. Other storm water treatment devices that have similar treatment effectiveness but are less attractive to sensitive species and vectors should be considered as more practicable BMPs. Monitoring of the wet pond will provide the data necessary to compare its water quality performance with the performance of other technologies.

REFERENCES

Caltrans Storm Water Management Program, 1999, *1998-99 Data-Reporting Protocols*, California Department of Transportation, Environmental Program, Sacramento, CA

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