A Preliminary Assessment of Design Criteria for Vector Prevention in Structural Best Management Practices in Southern California

CALIFORNIA DEPARTMENT OF HEALTH SERVICES

VECTOR-BORNE DISEASE SECTION

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Introduction and Background

The importance of managing stormwater runoff is well known among transportation and stormwater management agencies and municipalities across the country. Federal and state laws regulating stormwater runoff have several purposes such as flood control, erosion control, improvement of water quality, and re-charge of underground aquifers. In recent years, stormwater management strategies have fallen under increasingly stringent regulations requiring the implementation of what have been termed Best Management Practices (BMPs). In general, BMPs serve to reduce the adverse environmental impact of human activities through the improvement of existing strategies or by the creation of new ones. BMPs for stormwater management may include modifying activity schedules, prohibitions or modifications of practices, maintenance procedures, etc. Best Management Practices may also involve the use of structures such as retention and detention ponds, swales, ditches, channels, vaults, infiltration basins, filtration systems and others.

The California Department of Transportation (Caltrans) is the agency responsible for managing California's state highway system. Its Storm Water Program has two primary goals: to comply with requirements of the federal Clean Water Act and resulting National Pollution Discharge Elimination System (NPDES) permit and other state requirements, and to provide the most cost-effective solutions for mitigating the harmful effects of stormwater runoff. In 1997, Caltrans began an extensive program plan to retrofit 32 selected facilities with 39 structural BMPs in Los Angeles (Caltrans District 7) and San Diego Counties (Caltrans District 11). These BMPs included biofiltration strips and swales, various media filtration technologies, extended detention basins, infiltration basins and trenches, continuous deflective separators, an oil/water separator, drain inlet inserts, and a wet basin. Construction began in September 1998 and was almost entirely completed during the following six months. There are currently 37 operational BMPs that are being monitored (2 remain to be constructed in Caltrans District 7), including 24 in Caltrans District 7 at 19 sites, and 13 in Caltrans District 11 at 12 sites.

The purpose of the Caltrans BMP Retrofit Pilot Study was to evaluate the water quality benefits and cost effectiveness of various structural designs retrofitted into

existing locations including freeways, interchanges, park and ride facilities, and maintenance stations. Potential negative consequences of these efforts may include direct impacts on the operations of vector control agencies and public health by increasing habitat availability for disease vectors[1] and nuisance pests. In 1998, the California Department of Health Services, Vector-Borne Disease Section (VBDS) entered into a Memorandum of Understanding (MOU) with Caltrans to provide technical expertise regarding vector production and the potential of vector-borne diseases within its stormwater BMP Retrofit Pilot Study. It was the intent of this MOU to protect public health by documenting and, where possible, mitigating vector production and harborage at the BMP study sites. The agreement required VBDS to establish a comprehensive vector surveillance and monitoring study, develop vector abatement protocols, and recommend appropriate engineering modifications to Caltrans BMPs that would reduce the potential of these structures to produce or harbor vectors. In addition to reviewing the BMP design criteria and monitoring maintenance and operations, VBDS conducted studies to identify which of these designs were least conducive to vector production.

The following report is based on observations and data obtained from weekly BMP site visits that began in early May 1999 and ran through April 2001. During this two-year study, numerous design features and operational events resulted in water accumulating and standing within BMP structures for various lengths of time. Standing water provided the habitat needed for the development of certain vectors, particularly mosquitoes. Caltrans attempted to resolve the design and maintenance issues that allowed vector breeding based on recommendations made by VBDS and the local vector control districts, and successfully implemented solutions to many of them. The purpose of this report is to address design features and other factors that created suitable habitat for the propagation of vectors within BMPs and provide corrective and/or preventative recommendations for future designs. This study provides an initial assessment of design criteria for vector prevention within stormwater structures.

[1] California Health & Safety Code, Section 2200. “Vector" means any animal capable of transmitting the causative agent of human disease or capable of producing human discomfort or injury, including, but not limited to, mosquitoes, flies, other insects, ticks, mites, and rodents.

Vector Surveillance, Monitoring, and Abatement

In accordance with the MOU, VBDS staff established comprehensive vector surveillance and monitoring plans for the 37 operational BMP devices conducted in collaboration with Greater Los Angeles County Vector Control District (GLACVCD), San Gabriel Valley Mosquito and Vector Control District (SGVMVCD), Los Angeles County West Vector Control District (LACWVCD), and San Diego County Vector Surveillance and Control (SDCVSC) in their respective jurisdictions. The primary tasks of the local vector control districts were weekly monitoring of all BMP study sites for immature stages of mosquitoes and midges. At the same time, VBDS staff maintained an overall independent surveillance schedule to monitor vegetative cover, predators of immature mosquitoes, physical and chemical properties of water, and evidence of rodent and other vector populations.

Several mosquito abatement procedures are currently accepted in California. For immature stages, control can be achieved by using microbial larvicides (*Bacillus thuringensis* var. *israelensis* [Bti]; *Bacillus sphaericus*), insect growth regulators (i.e. methoprene), and/or mosquitocidal oils that create a surface film (e.g. Witco® Golden Bear GB1111). For adults, pyrethroid insecticides may be applied as space sprays by air or ground equipment. A single vector abatement regimen was prepared by VBDS and implemented by the collaborating vector control districts as needed. A liquid formulation of methoprene (Altosid EC®: a juvenile hormone mimic that inhibits successful development of immature mosquitoes and a variety of midges) was selected because of its short residual activity, extremely low environmental toxicity, and negligible effects on larval population dynamics.

General Design and Maintenance Recommendations

A variety of vector species including mosquitoes, midges and rodents may utilize artificial habitats created by BMP structures designed to receive stormwater runoff. The following design and maintenance recommendations serve to prevent or reduce vector habitats within BMPs; however, the impacts, if any, of these recommendations on the intended pollutant removal efficiency of the structures are not addressed. During this two-year study, mosquitoes were found to be the most significant and persistent vectors associated with BMP structures. Because of this, recommendations focus primarily on preventing standing water, which is needed for the development of immature mosquitoes.

Stormwater BMPs are intended to have minimal operational oversight and maintenance; thus it is critical to design facilities in as simple a manner as possible. As a general recommendation, all BMP structures should be easily and safely accessible (e.g. avoid structures that fall under the definition of "confined space") to allow vector control personnel to effectively monitor and, if necessary, abate vectors. If utilizing covers, spring loaded or light weight access hatches should be included in the design that open easily and allow for sampling of vectors. Covers should seal completely. Mosquito larvicides are applied with hand held equipment at small sites and with backpack or truck mounted high-pressure sprayers at large sites. The effective swath width of most backpack or truck mounted larvicide sprayers (liquid or granule) is approximately seven meters on a windless day. As a result, road access (with provisions for turning a full-size work vehicle) should be provided along at least one side of large above-ground BMPs that are less than seven meters wide. Those BMPs that have shoreline-to-shoreline distances in excess of seven meters should have a perimeter road for access to both sides. It is important not to have vegetation and/ or other obstacles between the access road and the BMP that might obstruct the path of larvicides to the water; thus, roads should be built as close to the shoreline as possible. The periodic removal or mowing of invasive cattails and/ or other tall wetland vegetation including shrubs and trees is necessary.

The following criteria should be incorporated into the design of all structural BMPs to reduce the probability of mosquito breeding.

Dry Systems

1. Structures should be designed such that they not hold standing water for more than 72 hours (the minimum length of time for mosquito development). Provisions to prevent or reduce the possibility of clogged discharge orifices (e.g. debris screens) should be incorporated into the design. The use of weep holes are not recommended due to rapid clogging when adjacent to or within a sediment-laden area.
2. The hydraulic grade line of each site should be a primary factor in determining the appropriate BMP that will allow water to flow by gravity through the structure. (Pumps are subject to failure and require sumps that hold water and may create mosquito habitats. Structures that do not require pumping should be favored over those that do).
3. Designs should avoid the use of rip rap or concrete depressions that may hold standing water.
4. Distribution piping and containment basins should be designed with adequate slopes to drain fully and prevent standing water. The design slope should take into consideration buildup of sediment between maintenance periods
5. The use of barriers or diversions that result in standing water should be avoided.

Systems with Sumps or Basins

Structures designed with sumps or basins that retain water permanently or semi-permanently (e.g. MCTT, CDS, Delaware-type sand media filters, Canister-type media filters) should be sealed completely against adult mosquitoes. Adult female mosquitoes may utilize openings as small as 1/16th of an inch to access water for egg laying.

1. Structures should be designed with the appropriate pumping, piping, valves, or other necessary equipment to allow for easy dewatering of the unit if necessary.
2. If the sump or basin is completely sealed, with the exception of the inlet and outlet, the inlet and outlet should be fully submerged so female mosquitoes have access to only a limited surface area of water for egg laying.

Permanent Ponds

1. Permanent ponds should maintain water quality sufficient to support surface-feeding fish such as mosquitofish, *Gambusia affinis*, which feed on mosquito larvae.
2. Permanent pond shorelines should be accessible to both maintenance and vector control crews for: 1) periodic maintenance and/or control of emergent and pond-edge vegetation, and 2) for routine monitoring of mosquito immatures and abatement procedures, if necessary. Emergent plant density should be controlled so that natural mosquito predators are not inhibited or excluded from pond edges (i.e. fish should be able to swim between plant bases).
3. If possible, permanent ponds should be maintained with depths in excess of 4 feet to preclude invasive emergent vegetation such as cattails. The pond edges below the water surface should be fairly steep and uniform to discourage dense plant growth and reduce favorable mosquito habitat.
4. Rip rap or liners should be used in areas where vegetation is not necessary, to prevent unwanted growth.
5. Permanent ponds should be designed to allow for easy dewatering of the basin when needed.

Treatment Technologies

Biofiltration Strips and Swales

Design Criteria. Biofiltration swales and strips are densely vegetated BMPs that filter stormwater as it flows over and through vegetation. Biofiltration strips are broad vegetated surfaces that receive stormwater sheet flow directly from an impermeable surface and allow it to flow through in relatively thin sheets. In contrast, biofiltration swales are conveyance channels (typically trapezoidal shaped) that receive captured runoff. In the Caltrans BMP Retrofit Pilot Study, one strip and six swales were built to treat stormwater runoff from sections of freeway. The criteria for the vegetation required that it filter suspended solids, withstand a typical one-year storm event in southern California, adapt to the local climate, tolerate periods of high and low moisture, be slow growing, and require minimum maintenance. A species of grass, "saltgrass", met most of these criteria and was used exclusively in biofiltration structures. Figure 1 shows a typical biofiltration swale and biofiltration strip.

Monitoring Results. The four biofiltration swales in Caltrans District 7 incorporated energy dissipaters composed of small rock rip rap housed in shallow concrete depressions. During their first few months of operation, these energy dissipaters retained water following storm events and irrigation of saltgrass, and provided habitat for immature mosquitoes. In October 1999, the energy dissipaters were modified per VBDS and GLACVCD recommendations by filling the rip rap depressions with concrete and imbedding rocks into it. Following this modification, no other vector sources were detected at these sites. Mosquitoes and other vectors were not detected at the two biofiltration swales in Caltrans District 11 or at the biofiltration strip in Caltrans District 7 during this study.

Design Recommendations. With the exception of the original energy dissipaters used in Caltrans District 7, biofiltration strips and swales did not pond significant amounts of water during this study. Energy dissipaters that do not hold water are recommended (e.g. rocks embedded into concrete). Figure 2 shows biofiltration swale

inlet modifications that were made at sites in Caltrans District 7 to prevent accumulations of standing water.

Operation and Maintenance. Maintenance of biofiltration swales included monthly visual inspections during the wet season for evidence of ponding and channeling. Any ponding or channeling noted was corrected within ten days. Vegetation height was maintained at less than ten inches and barren spots were re-planted during the fall season. The maintenance that was performed was adequate to prevent ponding of water and breeding of mosquitoes; however, Figure 2 illustrates sediment build-up outside a biofiltration swale inlet pipe that could lead to standing water if not maintained regularly.

Biofiltration strip.
8/25/00
I-605 & SR 91

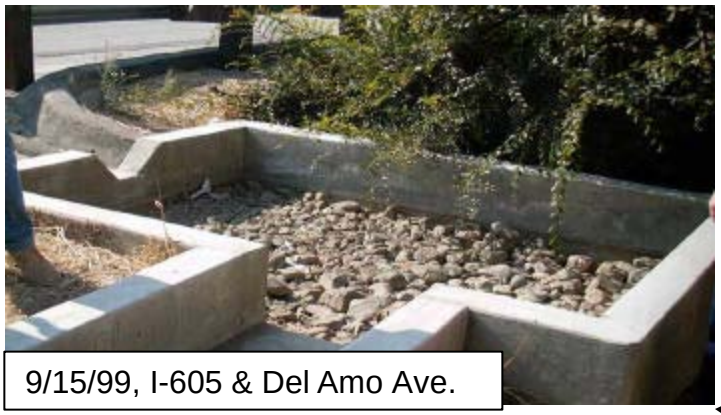
Biofiltration swale.
10/13/99
SR 78 & Melrose Ave.

Vector Prevention in Structural BMPs

Figure 1. Biofiltration Strips & Swales

State of California, DHS Vector-Borne Disease Section

Early-style energy dissipater. Rip rap depression holding water.
9/15/99
I-5 & I-605



9/15/99, I-605 & Del Amo Ave.

8/25/00
I-5 & I-605

Modified energy dissipaters grouted in to prevent standing water.

Inlet area subject to sediment build-up and subsequent ponding.
1/25/01
Cerritos MS

Vector Prevention in Structural BMPs

Figure 2. Inlets to Biofiltration Swales

State of California, DHS Vector-Borne Disease Section

Filtration Technologies

Media filters remove sediment and particulate pollutants from stormwater runoff. They are used for treating relatively small areas such as parking lots and maintenance yards. In general, water is directed into a sedimentation or settling vault where larger particulates settle out and accumulate on the bottom. From there, water is slowly released to a second filtering vault where fine particulates are removed as water percolates through a media matrix. Four filtration technologies (Austin, Multi-Chambered Treatment Train [MCTT], Canister, and Delaware) are included in 9 different structures of the Caltrans BMP Retrofit Pilot Study.

1) Austin-Type Sand Media Filters

Design Criteria. The design criteria for Austin-type sand media filters were originally developed in Austin, TX. A total of five structures were constructed for the Caltrans BMP Retrofit Pilot Study; three in Caltrans District 7 (Foothill and Eastern Regional Maintenance Stations and Termination Park and Ride) and two in Caltrans District 11 (La Costa Park and Ride and I-5 & SR 78 Park and Ride). These were designed to handle a 1-year, 24-hour storm in southern California.

Austin-type sand media filters consist of sedimentation vaults followed by sand media filter vaults. Sedimentation vaults were built 7-16 feet deep with a length to width ratio of 2:1, a slope of 0.1%, and a design detention time of 24 hours. They were designed with a 6 inch (150 mm) diameter PVC riser pipe with sized discharge orifices that draw down water slowly over time by gravity to a spreader trough in the sand media filter vault. If needed, a gate valve at the PVC riser connection in the sedimentation vault could be closed to detain water.

The sand media filters were designed to operate at a filtration rate of 0.0545 gpm/sq.ft (10.5 ft/d) assuming an average hydraulic head of 3 feet. The sand media consisted of 18 inches of 0.02 to 0.04 inch diameter sand over a layer of ½-inch to 2-inch diameter gravel. The sand and gravel were separated by a layer of geotextile fabric. The underdrain is a 6-inch diameter pipe with four-inch diameter laterals at a slope of 1%. The perforations are ½ inch on both sides of the pipe.

Because of the hydraulic grade line of the structures in Caltrans District 7, it is necessary to pump the filtered effluent into the storm drain system. The pumping system consists of a sump pump from the sand media filter bed, at the bottom of a 900 mm diameter vertical corrugated polyethylene pipe located approximately six feet below the surface of the sand media. The vertical corrugated polyethylene pipe was originally designed to be open to the atmosphere.

The design of Caltrans District 11 structures differed slightly from those built in Caltrans District 7. The sand media filters were built in line with the hydraulic grade line of the storm drain system and therefore, no pumping to the storm drain is required. This eliminated a potential habitat for immature mosquitoes.

Monitoring Results. Austin-type sand media filters regularly provided suitable aquatic habitats for immature mosquitoes following storm events. The two Caltrans District 11 sites, La Costa Park and Ride and the I-5 & SR 78 Park and Ride held standing water in spreader troughs and occasionally in the sedimentation vaults due to clogging and sediment build up. The spreader troughs at these sites were slightly modified to clear 4 inch diameter PVC connecting pipes, which unintentionally created persistent pockets of standing water. In Caltrans District 7, the three structures occasionally retained water in the spreader troughs, whereas sedimentation vaults occasionally retained water due to clogged pipes and/or failed effluent sump pumps. Standing water accumulated in a corner of the sedimentation vault of the Termination Park and Ride site due to a faulty grade.

Design Recommendations. In general, Austin-type sand media filters functioned as intended during this study; however, the following recommendations should be considered for future designs to minimize potential vector habitats. Figure 3 illustrates some examples of vector habitats created by these structures.

1. Pump sumps hold water and provide habitat for immature mosquitoes. In addition, these sumps cannot be sampled easily due to their depth and inaccessibility. Where possible, the installation of pumps and sumps

should be avoided. Where pumping cannot be avoided, a "mosquito proof" material should be installed over the top of the sump to prevent mosquitoes from accessing water.

2. It is critical that design plans, particularly hydraulic grades, are carefully adhered to during construction. The design slope of 0.1% in the sedimentation vaults was acceptable for proper drainage; however, the Termination Park and Ride site was constructed with a faulty grade in the sedimentation vault, which resulted in standing water that accumulated opposite the PVC riser pipe.
3. Spreader troughs designed to deliver water uniformly to adjacent sand media filters frequently hold water for long periods of time. Future designs should avoid the use of spreader troughs, or ensure that they hold water for no more than 72 hrs.

Operation and Maintenance. There are numerous maintenance issues associated with the Austin-type sand media filters that should be performed on a regular basis and are critical to prevent standing water and associated vector production. Any mosquito proofing materials (i.e. mosquito nets) should be inspected frequently and replaced annually as part of routine maintenance. Regular inspections should also include checking for clogged pipes or other vital components, measuring debris depth in the sedimentation vault, checking effluent pump function, and monitoring sand media filter performance. Appropriate maintenance should be performed based on inspections or as needed.

Proper and timely removal of sediment and debris from the sedimentation vault is necessary to prevent standing water as well as growth of opportunistic plants and the production of vectors that utilize exposed aquatic habitats with soil-lined bottoms for reproduction, particularly midges. During the course of the study, sedimentation vaults were inspected monthly during the wet season for sediment depth and were designed to be cleaned when the depth of sediment reaches 12 inches or greater. Cleaning of the sedimentation vaults was not required during the study period.

Where effluent pumps were installed, proper maintenance or a back-up system is necessary to ensure that water does not back up into the sedimentation and sand filter media vaults. Because the sand media filters are not backwashed, it is necessary to remove the top layer of sand media and replace it whenever draw down time exceeds 48 hours. Failure to remove and replace clogged sand media will result in inadequate filtration rates and ponding of water in the vaults. Removal of the top 2 inches of sand in these structures was necessary after approximately two years due to clogging.

Standing water in sedimentation vault
due to faulty grade.
10/5/99, Termination P&R

Standing water in sedimentation vault
due to clogged pipe.
12/00, La Costa Ave. P&R

Standing water in spreader trough.
10/5/00
Foothill MS

Mosquito netting on effluent pump sump in
sand media filter vault.
8/16/00, Foothill MS

Vector Prevention in Structural BMPs

Figure 3. Austin-Type Sand Media Filters

State of California, DHS Vector-Borne Disease Section

2) Multi-Chambered Treatment Trains (MCTT)

Design Criteria. Functionally, MCTT technology is similar to that of Austin-type sand media filters. MCTTs consist of a catch basin, a sedimentation vault with tube settlers and floating sorbent pads, and a sand/peat media filtration vault. Two MCTTs were constructed in Caltrans District 7 (Via Verde Park and Ride and Lakewood Park and Ride).

As part of the original design, the catch basin contained several mesh bags full of plastic "aeration balls" at the outlet of the influent pipe. These were supported on a grate above the water in the catch basin and served to facilitate removal of volatile organic compounds from stormwater as it passed through them. The bags were later removed for several reasons: 1) they did not provide significant removal of pollutants, 2) they clogged with trash and leaves, and 3) they prevented vector control personnel from monitoring the standing water below the support grate. As a result, no vector monitoring samples were collected from the catch basin prior to October 24, 2000.

From the catch basin, stormwater flows via a pipe into a sedimentation vault with a detention time of 12 hours. The sedimentation vault contains inclined tube settlers that facilitate sedimentation from incoming stormwater as well as floating sorbent pads designed to remove hydrocarbons. The tube settlers sit on top of fiberglass grating located on 30 mm deep beams three feet from the basin floor. Water passes upward through the plastic tube settlers over a three-foot high weir into a pump sump from where it is pumped into an adjacent sand/peat media filter vault. The design and placement of the pump sump results in a permanent pool of standing water in the sedimentation vault.

Water is pumped from the sedimentation vault pump sump onto a 24-inch-deep filter media bed consisting of a 50/50 blend of sand and peat moss. A geotextile fabric sits on top of the media to eliminate scouring and prolong filter media life. Water is then pumped to the storm drain system from a second sump located below the media filter, similar in design and function to pump sumps described for Austin-type sand media filter vaults in Caltrans District 7.

Monitoring Results. During this study, immature mosquitoes were consistently detected in the sedimentation vaults of the MCTTs. Of all the BMPs monitored in this study, MCTTs produced the greatest number of mosquitoes for the longest periods of time. Vector monitoring and abatement became difficult when the water level in the sedimentation vault dropped below the top of the tube settlers, allowing each plastic tube to become a protected "microhabitat" for immature mosquitoes.

Design Recommendations. Because of the frequency and density of immature mosquitoes detected in the MCTT sedimentation vaults during the study, numerous changes were proposed and/or made. Figure 4 illustrates the complexity of MCTT structures and provides a photo of the sedimentation vault cover retrofit. The following are recommendations for modifications, or modifications that were made during course of the study in an attempt to reduce or minimize vector habitat:

1. No immature mosquitoes have been detected in the catch basins since the aeration bags were removed; however, the current covers are made of wood and have wide gaps between the planks, which could allow mosquitoes to access the water below. Since the catch basins hold standing water permanently, the wood covers should be replaced with sealed units.
2. The pump sump design in the media filter vault is almost identical to those built for Austin-type sand media filters in Caltrans District 7. Pump sumps hold water and provide habitat for immature mosquitoes. In addition, these sumps cannot be sampled easily due to their depth and inaccessibility. Where possible, the installation of pumps and sumps should be avoided. Where pumping cannot be avoided, a "mosquito proof" material should be installed over the top of the sump to prevent mosquitoes from accessing water.
3. Several steps were taken to prevent mosquitoes from accessing permanent standing water present in multiple locations of the MCTTs. The effluent pump sump in the media filter vault was covered with fine-

mesh cloth. An aluminum cover was installed over the settling chamber during February 2001 (the influent pipe to the sedimentation vault is submerged in the catch basin). All joints at openings and hatches are constructed with tongue and groove joints and are sealed with gaskets meeting ASTM standard C 509. A smoke test was conducted to ensure that the covers were airtight. Vents for the basin were covered with a fine-mesh screen. No mosquitoes have been detected since the covers were installed. Further monitoring will be necessary to validate the effectiveness of the covers.

Operation and Maintenance. Where pumps were installed, proper pump maintenance is necessary to ensure that water does not back up into the sedimentation and media filter vaults. Because the media filters are not backwashed, it will be necessary to periodically remove the top layer of filter media and replace it. The media should be replaced whenever the drain time is greater than 72 hours or sediment accumulation is greater than 0.1 inch over more than 50 percent of the fabric surface area. Failure to remove and replace clogged filter media will result in standing water on the filter surface. The filters in this study were functional for over two years. It has not been necessary to replace media.

The biggest factor contributing to mosquito production was the fact that the sedimentation vault held water continuously. In an initial attempt to mitigate this, the sedimentation vault was pumped out annually on May 1, to avoid standing water during the dry summer months when mosquitoes are most abundant. However, even with pumping, it took several weeks for the vaults to dry completely, and mosquito breeding continued into the summer months. This maintenance was not an adequate solution to prevent breeding of mosquitoes and weekly monitoring and abatement was necessary for months. The aluminum covers may preclude access to mosquitoes. Routine maintenance of the aluminum covers should include replacing gaskets whenever they deteriorate and ensuring that the hatches are properly closed each time after opening. In addition, routine inspection and/or replacement of all mosquito screens is necessary.

Tube settlers in sedimentation vault. Standing water under grate. 8/25/00

Standing water in sedimentation vault pump sump. 8/25/00

Catch basin. Standing water below hinged grate. 2/08/01

Vector sampling below grate in sedimentation vault. 9/15/99

Retrofit aluminum cover over sedimentation vault. 3/26/01

Vector Prevention in Structural BMPs

Figure 4. Multi-Chambered Treatment Trains (MCTT) (Lakewood P&R)

State of California, DHS Vector-Borne Disease Section

3) Canister-Type Media Filter

Design Criteria. A single canister-type media filter manufactured by Stormwater Management Inc. (StormFilter™) was included in the Caltrans BMP Retrofit Pilot Study and installed at the Kearny Mesa Maintenance Station in Caltrans District 11. This BMP was built below ground and consists of sedimentation followed by treatment through canister filters containing a mixture of perlite/zeolite. The Kearny Mesa MS unit was built with a primary catch basin followed by three in-line canister filter vaults designed to handle a one year, 24 hour storm in southern California. Water moves through the structure via 12-inch diameter pipe. The influent pipe delivers water to an initial catch basin designed to remove large sediments and debris. Water then flows to a second, smaller catch basin located in the first canister filter vault. Water is directed over a weir, through a flow spreader, and into contact with the canister filters through which it passes to the storm drain.

According to the manufacturer's design criteria, 30 canisters are needed for each cfs of stormwater. As a result, three canister filter vaults (8 ft deep by 80 ft^2), containing a total of 81 perlite/zeolite filter canisters were included in the Kearny Mesa MS design. These vaults fill sequentially depending on the volume of stormwater runoff and the canister filters operate at a minimum hydraulic head of 2.3 feet. Each canister filter vault has a depression at the inflow designed to spread the flow of water. Because of its design, standing water remains permanently in both catch basins as well as in the spreader depressions.

The catch basin and the three canister filter vaults are sealed from above with aluminum covers. Covers were installed with spring-loaded doors for easy access, but were not completely sealed to prevent the entry of mosquitoes. Figure 5 illustrates the different components of the canister-type media filter.

Monitoring Results. Mosquito immatures were detected in the two catch basins as well as in the spreader troughs of the canister filter vaults. The aluminum covers may have reduced mosquito access to the standing water below, but gaps around and between the doors as well as small spaces around the door handles allowed many adult females to enter and lay eggs.

Design Recommendations. Several design features of the canister-type media filter allowed mosquito access to permanent sources of nutrient-rich standing water. The following are recommendations that should be considered in future designs to prevent or reduce vector production.

1. The sediment catch basins should not hold permanent standing water. They should be designed to drain down rapidly (72 hours or less).
2. Flow spreaders in the canister filter vaults should be designed to eliminate standing water.
3. If standing water must be present, access covers should be designed with adequate gaskets to prevent entry of mosquitoes. In addition, the potential for mosquitoes to access standing water under covered vaults via inlet or outlet pipes should be addressed.

Operation and Maintenance. Maintenance of these units includes changing out the filter media whenever it is discolored and packed with sediment and removing the sediment when it reaches 12 inches in the catch basin. Other necessary maintenance may include dewatering the unit during the summer months or routine treatment with a mosquito larvicide if breeding persists.

Standing water in
sediment catch basin.
8/17/00

Filter canisters containing a
mixture of perlite/zeolite media.
8/17/00

Aluminum covers over vaults.
8/17/00

Vector Prevention in Structural BMPs

Figure 5. Canister-Type Media Filter (Kearny Mesa MS)

State of California, DHS Vector-Borne Disease Section

4) Delaware-Type Sand Media Filter

Design Criteria. The design criteria for Delaware-type sand media filters were originally developed in the State of Delaware. A single Delaware-type sand media filter was included in the Caltrans BMP Retrofit Pilot Study and installed at the Escondido Maintenance Station in Caltrans District 11. This stormwater BMP was built below ground and consists of a sedimentation vault followed by a sand media filter vault designed to handle a one-year, 24-hour storm in southern California, with a total filter surface area of 720 ft^2 per acre of tributary area (the sedimentation chamber volume is 540 cubic feet per acre of tributary area). Stormwater flows from the maintenance station grounds to a 36" culvert and into the sedimentation vault. The sedimentation vault was constructed parallel to a sand media filter vault. To reach the sand media filter vault, the water level in the sedimentation vault must reach approximately 36 cm in depth and flow over a weir (1.5 feet of hydraulic head is required for filtration through the sand media). Standing water remains in the sedimentation vault permanently.

An 8-inch (200 mm) bypass line and gate valve are located at the end of the sedimentation vault to allow it to be dewatered for maintenance. This valve is normally closed; however, some water unintentionally seeps past, slowly draining the sedimentation vault until water only a few centimeters in depth remains.

The sedimentation and sand media vaults were sealed from above by heavy steel doors; however, the covers do not adequately seal to prevent entry of mosquitoes. In addition, the heavy steel doors do not have springs to allow for reasonable access to this structure. Figure 6 illustrates the different components of the Delaware-type sand media filter.

Monitoring Results. Small gaps between the individual steel doors allowed adult mosquitoes to access the standing water found in the sedimentation vault. This water, often as shallow as 1 inch, provided adequate habitat for immature mosquitoes.

Design Recommendations. Several design features of the Delaware-type sand media filter allowed mosquito to access the permanent standing water in the

sedimentation vault. The following are recommendations that should be considered in future designs to prevent or reduce vector production.

1. The weir between the sedimentation and sand media filter vaults results in permanent standing water in the sedimentation vault. The structure should not hold permanent standing water.
2. The sedimentation vault should be designed to drain down rapidly (72 hours or less) to prevent standing water. The slope of the sedimentation vault should be increased slightly to allow for proper and complete drainage when necessary.
3. Adequate gaskets need to be provided with covers to prevent entry of mosquitoes. In addition, future designs should include the use of lightweight aluminum and/or spring-loaded covers to improve access for maintenance and/or vector monitoring.

Operation and Maintenance. Delaware-type sand media filters require maintenance in several areas to prevent or reduce vector production, including sand media filter maintenance, sediment removal, and proper draining of the sedimentation basin between storm events.

Since the sand media filters are not backwashed, it is necessary to remove the top layer of sand filter media and replace it whenever there is excessive buildup of sediment or when the filtration rate drops to less than 9 ft per day. Failure to remove and replace sand media when it is clogged will result in inadequate filtration rates and ponding of water on the filter surface. The sand filter media in this structure was changed after approximately two years due to clogging.

Proper and timely removal of sediment and debris from the sedimentation basin is necessary to prevent standing water and the production of vectors. During the course of the study, the basin was inspected monthly during the wet season for sediment depth and was designed to be cleaned when the depth of sediment reached 12 inches or greater. The sedimentation basin was cleaned out and replaced in February 2001, with only a few centimeters of accumulated sediment build-up.

Provided that adequate time has passed for settling of suspended solids, the valve at the end of the sedimentation vault should be opened to allow the basin to drain between storm events and particularly prior to the summer months.

Heavy steel covers over sedimentation and sand media vaults. 1999

Sand media filter vault. 8/17/00

Sampling standing water for vectors in sedimentation vault. 1999

Vector Prevention in Structural BMPs

Figure 6. Delaware-Type Sand Media Filter (Escondido MS)

State of California, DHS Vector-Borne Disease Section

Extended Detention Basins (EDB)

Design Criteria. An EDB is a shallow depression lined with bare soil, vegetated soil, or concrete. Stormwater runoff is directed into these basins from where it slowly drains down (48-72 hours) into the storm drains by means of an outlet structure with appropriately sized discharge orifices. The extended detention period allows sediment and other pollutant particulates to settle to the floor of the structure, resulting in a cleaner effluent. Five EDBs were constructed as part of the Caltrans BMP Retrofit Pilot Study, two in Caltrans District 7 and three in Caltrans District 11. Each structure is unique in size and shape, and several have additional design features not found in others; however, they all have the same intended function. Figure 7 illustrates several examples of EDBs and their design and maintenance concerns.

Monitoring Results. No vector issues were detected at three of the soil-lined EDBs (two in Caltrans District 11 and one in Caltrans District 7) during this study; however, the remaining two sites had features that provided suitable habitat for immature mosquitoes.

The I-5 & I-605 EDB in Caltrans District 7 was built with a concrete-lined bottom. The effluent drained through discharge orifices in a PVC pipe that led into a $3ft^2$ concrete outlet sump, approximately 22 inches below the main exit pipe. This design resulted in a permanent pool of standing water as well as consistent mosquito production. The sump was modified and filled in February of 2001. No standing water or vector production has been detected at this site since.

The I-5 & SR-56 site (Sorrento Valley) in Caltrans District 11 incorporated two large rock rip-rap zones placed over filter fabric: one at the inlet to the basin (approximately 13 x 12 ft) and one in the center section of the basin (approximately 17 x 90 ft). An unintended consequence of this design feature was that over time, the rip rap created depressions in the basin floor up to 12 inches deep, despite the underlying filter fabric, that resulted in an attractive habitat for mosquitoes,. Water entering this basin drains at approximately the prescribed rate from the outflow, but the rip rap depressions do not infiltrate well and hold standing water for weeks. This habitat between the rocks not only protected larvae from potential predators and sunlight, but also effectively hid

them from vector control inspectors and made effective abatement difficult or impossible. In addition, VBDS noted that irrigation water runoff from a nearby hillside contributed to the water source present in the rip rap depression closest to the mouth of the influent pipe.

Design Recommendations. With the exception of the I-5 & SR 56 site, Caltrans EDBs generally did not hold significant amounts of standing water. Several recommendations pertaining to EDBs are listed below and should be considered in future designs to prevent or reduce vector production.

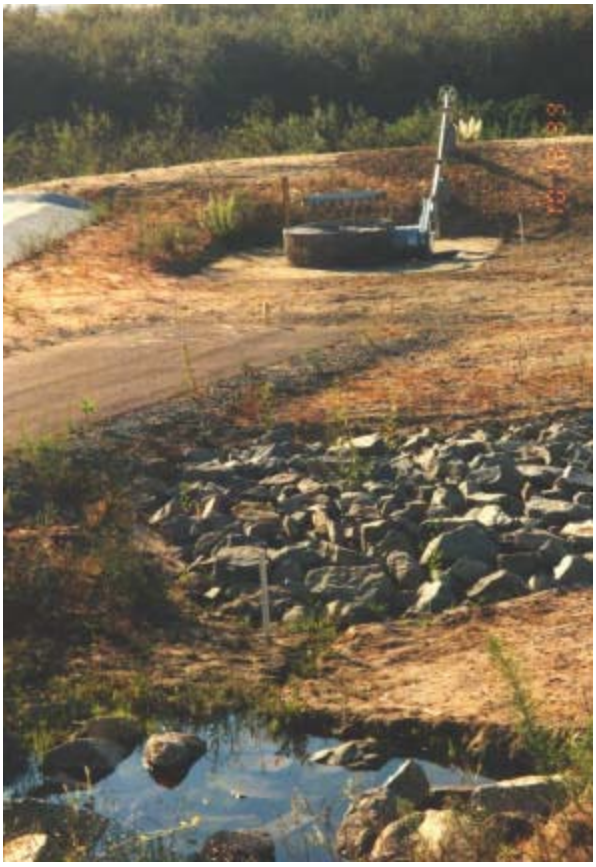
1. Avoid the use of sumps that hold water. The sump at the south end of the I-5 and I-605 EDB basin held water permanently. Initially, the sump was routinely pumped dry, but this maintenance had to be terminated due to water discharge regulations, resulting in mosquito production.
2. Avoid the use of loose-rock rip rap. Mosquitoes and other vectors are highly attracted to protected aquatic habitats. The I-5 and SR-56 site drained adequately with the exception of the rip rap zones where water collected between the rocks. The rip rap at the inlet of this basin should be replaced with rock embedded into concrete. The rip rap in the middle of the basin should be removed.

Operation and Maintenance. Routine sediment removal and control of invasive vegetation as well as frequent inspections of the outlet debris screen and discharge orifices are critical to the prevention of standing water in EDBs. During the course of this study, EDBs were inspected following every storm event. Debris was removed from the outlet screen when necessary and vegetation was trimmed and/or removed at least once per year. Sediment is scheduled for removal when it reaches 18 inches in depth or fills 10% of the basin volume, whichever is less. Further monitoring will be required to determine if the proposed sediment removal schedule will be adequate. During the course of the study, no sediment removal was required.

I-5 & Manchester Ave.

Recently completed. 10/13/99

Sediment and vegetation build-up around inlet. Subject to ponding. 3/26/01



Standing water in rip rap depressions.
10/13/99
I-5 & SR 56

Concrete-lined basin.
8/25/00
I-5 & I-605

Vector Prevention in Structural BMPs

Figure 7. Extended Detention Basins

State of California, DHS Vector-Borne Disease Section

Infiltration Basin/Infiltration Trenches

Design Criteria. Infiltration basins and trenches are depressions used to detain stormwater for a short period of time until it percolates to the groundwater table. During percolation, water is essentially filtered through the soil and pollutants are captured in site vegetation and soils by adsorption. Basins are used for large drainage areas such as freeways and store water in visible ponds whereas trenches are used for small drainage areas such as maintenance yards and store water out of sight within a gravel or aggregate matrix. In both designs, permeability has to be periodically restored by removing trapped sediments. The two infiltration trenches in the Caltrans BMP Retrofit Pilot Study (Altadena MS in Caltrans District 7 and at the Carlsbad MS in Caltrans District 11) are combined with biofiltration strips that function as a pre-filter. A single infiltration basin was built at the cloverleaf connector between northbound I-605 and westbound SR 91. The infiltration trenches are shown in Figure 8 while the infiltration basin is shown in Figure 9.

The Altadena Maintenance Station was designed with a biofiltration strip pre-filter that receives stormwater runoff before it reaches the infiltration trench. The biofiltration strip is approximately 25 ft x 64 ft, with a 2% slope. The curb-type flow spreader placed prior to the biofiltration strip can hold standing water permanently, if the plug located at the end of the curb is not removed to allow it to drain. The adjacent infiltration trench is filled with 3 feet of graded gravel and is approximately 30 x 62 ft. During this study, no standing water was ever detected in the trench.

The Carlsbad Maintenance Station was also designed with a biofiltration strip pre-filter followed by an infiltration trench. The biofiltration strip is approximately 91 feet long by 22 feet wide. Stormwater runoff is conveyed by a concrete swale through a partial flume to a concrete gutter, which acts as a side weir to spread flow over the length of the biofiltration strip, and was designed to handle runoff from a 25-year storm in southern California. Following the biofiltration strip, water is delivered to an infiltration trench designed to hold the volume from a one-year storm. The trench is 8 feet wide by 180 feet long. Infiltration rate was determined by two tests, which resulted in an I of 2.8 x 10^{-5} fps (8.7 x 10^{-6} m/s) average for the in-drill hole and 2.3 x 10^{-6} fps (7.1 x 10^{-7} m/s)

average for the laboratory sample. The total area of the trench (241 m^2) would give an 11-hour to 5.61-day detention time prior to percolation.

The infiltration basin at the I-605 & SR 91 was designed to handle flow volume from a 1-year, 24-hour storm in southern California. Water enters the basin from two locations: the first is a 300 mm plastic pipe on the east end of the basin with a 2% slope, the second is a 600 mm plastic pipe with a 1% slope on the south end of the basin. Outlets of both influent pipes into the basin have loose-rock rip rap energy dissipaters. Minimum infiltration rate of 1.94×10^{-4} cm/s was recommended in the design, which corresponds to a sand, loamy sand, sandy loam and silt loam soil group. Borings were collected which showed a soil with sandy material from 0.9 to 3.0 meters. From surface to 0.9 meters and 3.9 to 9.1 meters was sandy silt to clayey silt. Permeability rate was 1.6×10^{-4} cm/s, which was considered to be marginal. A detention time of 38 hours was estimated, based on a basin volume of 432 m^3, a depth of 0.22 m, and bottom surface area of 1,935 sq.m.

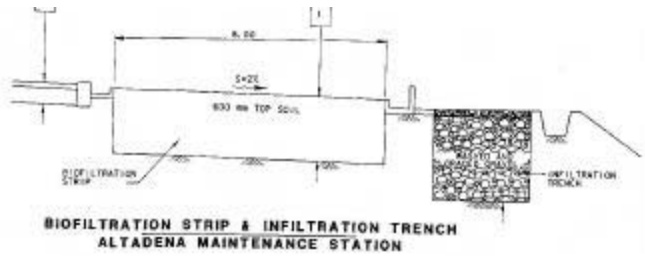
Monitoring Results. The two infiltration trenches and the infiltration basin percolated adequately during this study. No vectors were detected.

Design Recommendations. The primary concern with both the infiltration basins and trenches is ensuring adequate percolation to prevent standing water. Infiltration basins should not be constructed at locations that do not percolate due to improper soil type or high groundwater. The hydrogeology in California varies significantly from one site to the next and there are many locations that are not amenable to infiltration. Therefore it is important to develop statewide guidelines for evaluating sites and designing infiltration devices. To prevent standing water and mosquito production, standard design principles for infiltration basins should be followed such that standing water does not occur.

Operation and Maintenance. General guidelines for infiltration devices includes monitoring drain time after storm events, infiltration rates, depth to groundwater, sediment buildup, and condition of vegetation.

Properly designed infiltration basins require periodic maintenance to remove sediment, scarify the ground, or replant vegetation. Failure to conduct proper maintenance will result in reduced percolation rates and result in standing water.

In designs that include infiltration trench prefilters, such as the biofiltration strip prefilter at Altadena MS, the prefilter should be designed such that they do not hold standing water. The spreader trough at Altadena MS holds water after a storm event. In this design, the drain plug should be removed and the ditch drained within 72 hours of every storm event and the plug should be removed at the beginning of the dry season.



Typical design profile for an infiltration trench with a biofiltration strip prefilter.

Infiltration trench with biofiltration strip prefilter.
8/00
Carlsbad MS

Mosquito emergence traps above infiltration trench.
8/25/00

Altadena MS

Biofiltration strip prefilter. Spreader trough with standing water.
3/26/01

Biofiltration strip prefilter. Spreader trough drain plug. 08/25/00

Vector Prevention in Structural BMPs

Figure 8. Infiltration Trenches

State of California, DHS Vector-Borne Disease Section

11/17/00

8/25/00

Vector Prevention in Structural BMPs

Figure 9. Infiltration Basin
(I-605 & SR 91)

State of California, DHS Vector-Borne Disease Section

Continuous Deflective Separators (CDS)

Design Criteria. Continuous Deflective Separators (manufactured by CDS Technologies Inc.) are pre-cast, cylindrical devices designed to remove trash and debris, sand and sediments, and some oil and grease from stormwater runoff. The devices are typically placed downstream of drain inlets and installed below ground.

Two CDS units were installed in Caltrans right-of-ways as part of the BMP Retrofit Pilot Study, one located at I-210, east of Orcas Avenue and the other at I-210, east of Filmore Street. These were completed in early 2000, approximately 1 year after most of the other structures. Incoming stormwater runoff is directed by a weir from the storm drain at a 45-degree angle through an 8 x 12 inch rectangular opening into a cylindrical sump (3 ft diameter) where it creates a vortex. Debris, sand, and other large particles are deflected by this action into a debris basket at the bottom of the sump. Treated water passes through a metal screen (2400 micron screen at I-210, east of Orcas Avenue and 4800 micron screen at I-210, east of Filmore Street) and exits the unit through a 9 x 6 inch rectangular outlet, from where it flows by gravity back into the storm drain. By design, CDS devices hold permanent standing water in the cylindrical sump.

The CDS devices included in the Caltrans study are atypical installations. In most cases, CDS devices are installed completely below ground; however, the location of the Caltrans retrofit required that a portion of the device remain above ground. The influent and effluent pipes as well as approximately 20% of the cylindrical sump are above ground. Fiberglass lids were made for the sump and for the influent/effluent weir box. Two holes near the top of the sump support a rope that is attached to the debris basket to allow the basket to be lifted out of the unit for routine cleaning and maintenance. Figure 10 shows the east of Orcas Ave. site and illustrates many of the modifications made to the device in an attempt to prevent or reduce mosquito access to the permanent water in the sump.

Monitoring Results. The CDS devices provided a very attractive and accessible habitat for egg-laying adult mosquitoes. Adult female mosquitoes had multiple entrance points to access the sump water for egg laying including 1) the effluent pipe, 2) the

influent pipe, 3) the poorly sealed sump lid, 4) the poorly sealed weir box lid, and 5) the rope support holes in the sump. As a result, immature mosquitoes were extremely abundant in the nutrient-rich sump water.

Between November 2000 and January 2001, several modifications were made to the CDS devices in an attempt to "mosquito proof" the sumps. No mosquitoes have been detected since the modifications were made. Further monitoring will be necessary to validate the effectiveness of the modifications.

Design Recommendations. Because of the extensive mosquito production in these devices, numerous modifications were retrofitted to correct the problem. The modifications were limited by the design and installation of these particular devices, including the location of the hydraulic grade line; however, they were the most practical changes that could be made at these sites. The following is a list of modifications made to the CDS units in an attempt to eliminate vector production.

1. A ½ inch thick foam strip was glued to the weir box and CDS sump lids to eliminate access to mosquitoes through uneven sealing surfaces. In addition, the rope holes in the sump were sealed with caulk.
2. A mosquito net bag was installed over the effluent pipe to prevent entry of adult mosquitoes to the standing water in the sump. The first bag failed during high water flows and was modified to open during storm events and remain closed during periods of no flow.
3. The drain inlets to the CDS devices are located approximately 20 meters from the treatment sump (along the I-210) and could not be easily sealed against possible entry of mosquitoes. As a result, no changes were made to the inlet.

Permanent standing water will be present in the sumps of CDS devices by the nature of their design, unless they are pumped dry following every storm event. General recommendations for preventing mosquito access to the sumps in future CDS installations are provided below.

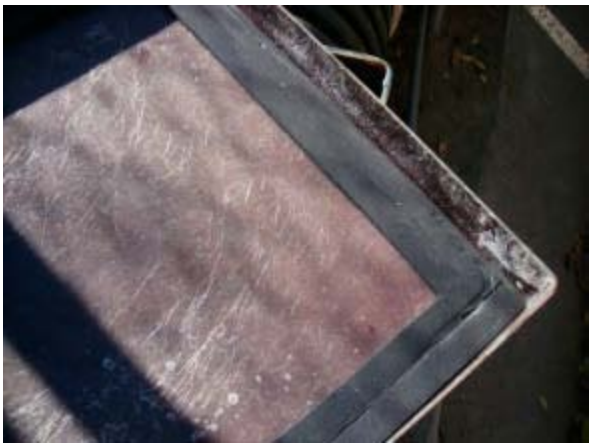
1. All lids or covers should seal tightly. If gaskets are present between the lid and the CDS device, they should be inspected periodically and replaced when necessary. Avoid lids with uneven sealing surfaces.
2. The inlet and outlet pipes to the device should be sealed or submerged to prevent access by mosquitoes. The inlet and outlet may be sealed either on the unit itself, or the inlet and outlet piping.
3. If the device cannot be properly sealed against mosquitoes, the sump should be pumped completely dry following every storm event. In addition, routine inspections should be made to check the sump for accumulation of water from illegal or non-stormwater discharges.
4. An alternative that may be considered is the inclusion of seep holes in the bottom of the sump that would allow the water to percolate into the ground. This would require testing to ensure that water can percolate into the soil. Percolation time should not exceed 72 hours and provisions to prevent or reduce the possibility of clogged seep holes should be incorporated into the design.

Operation and Maintenance. To prevent mosquito production during the summer months, water was pumped from the units in late May and taken off-site and the units were left dry until the fall storms. It was difficult to fully dewater the units, resulting in several inches of standing water at the bottom and continued mosquito breeding after dewatering. This maintenance alone was not adequate to prevent breeding of mosquitoes.

Ongoing maintenance will require routine inspections of all the mosquito proofing modifications including the sealing foam on the lids and the mosquito net bag on the effluent pipe. These should be replaced each year or as needed.

August 2000

Mosquito-proof bag on effluent pipe during storm. No end release for debris. 1/11/01



Foam seal on weir box lid. 11/17/00

Modified mosquito-proof bag on effluent pipe with end release for debris. 3/26/01

Foam seal for sump lid. 11/17/00

Vector Prevention in Structural BMPs

Figure 10. Continuous Deflective Separators (CDS) (East of Orcas)

State of California, DHS Vector-Borne Disease Section

Oil/Water Separator

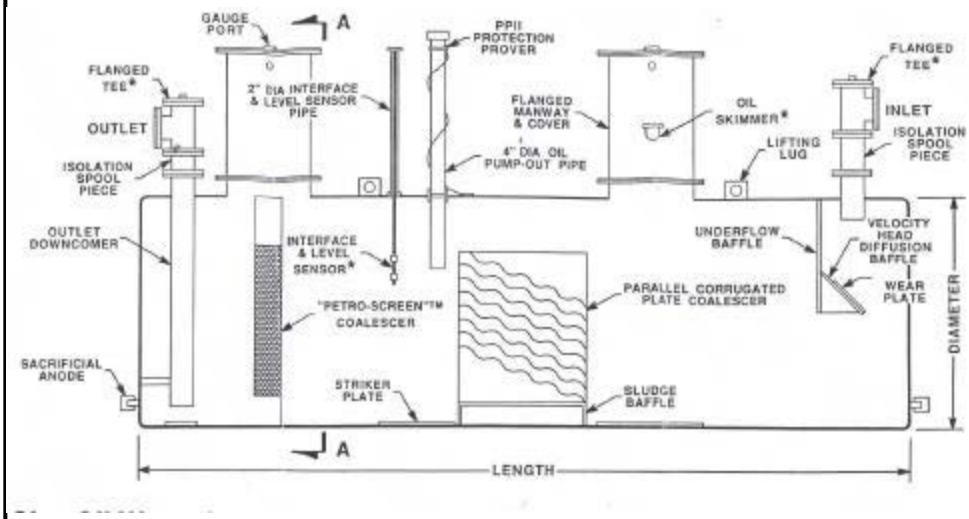
Design Criteria. A single oil/water separator device was included in the Caltrans BMP Retrofit Pilot Study and installed at the Alameda Maintenance Station in Caltrans District 7. The device consists of a cylindrical, horizontal, atmospheric steel vessel containing three separate sequential compartments. Stormwater runoff from the maintenance yard enters the first chamber through a flanged inlet pipe, which is located below the normal water surface level. Energy is dissipated by a head diffusion baffle located prior to the sedimentation chamber. A sludge baffle, which retains settleable solids, follows the sedimentation chamber. The water then enters an oil water separation chamber containing a removable polypropylene coalescer, designed to intercept oil globules. Water then exits the third chamber by gravity to the storm drain. The steel vessel was installed below grade with two covered access hatches above grade. Figure 11 provides design plans and an above-ground photo of the installed device.

Monitoring Results. During this study, immature mosquitoes were detected in a small plastic flume (not part of the oil/water separator) that held a small pool of standing water. This flume was used to monitor water flow during storm events. Although the oil/water separator is designed to hold standing water inside the steel vessel, no vectors were noted inside the structure. This is most likely due to the following reasons:

1. The steel vessel's inlet and outlet are both submerged.
2. Access ports into the vessel are tightly sealed.
3. Oil on the surface of the water inside the device may create lethal conditions for immature mosquitoes.

Design Recommendations. During the course of the study, this device did not harbor vectors. No modifications are recommended at this time.

8/25/00



Below-ground design plans.

Vector Prevention in Structural BMPs

Figure 11. Oil / Water Separator (Alameda MS)

State of California, DHS Vector-Borne Disease Section

Drain Inlet Inserts

Design Criteria. Proprietary drain inlet inserts (DII) filters by two manufacturers were included in the Caltrans BMP Retrofit Pilot Study; Fossil Filter™ (KriStar Enterprizes, Inc.) and Stream Guard™ (Foss Environmental). Fossil Filter™ inserts are trough-type devices filled with granular amorphous alumina silicate media, whereas the Stream Guard™ device is a sock-type insert made of a geotextile fabric. Both filters are designed to remove sediment (and adsorbed pollutants), oil, and grease. Three Caltrans maintenance stations in Caltrans District 7 were selected for DII retrofits including Foothill MS, Rosemead MS, and Las Flores MS. Each site was provisioned with both a Fossil Filter™ and a Stream Guard™.

Monitoring Results. During this study, no standing water was noted in the DII devices. However, each DII was provisioned with a small downstream, underground plastic effluent flume (not part of the DII) that held a small pool of standing water. These flumes were used to monitor water flow during storm events. Immature mosquitoes were detected in the Fossil Filter™ flume at Rosemead MS on several occasions.

Operation and Maintenance. Caltrans expended significant effort in the maintenance of DII devices to prevent debris from clogging the filters. Debris and trash were inspected and removed before and during each storm event. If these filters are not adequately maintained at this level, standing water and vector production could ensue.

Wet Basin

Design Criteria. Wet basins are permanent pools of water surrounded by a variety of wetland plant species. Stormwater from adjacent freeways and roadways and urban runoff is routed into these systems and pollutants are removed by physical and biological processes. Soluble nutrients in the water are reduced by plant uptake and constituents such as sediments, particulate trace metals, and organic nutrients settle and collect at the bottom of the basin. Wet basins maintain a permanent pool level. Only one wet basin was constructed as part of the Caltrans BMP Retrofit Pilot Study, located at I-5 and La Costa Ave. in Caltrans District 11.

The wet basin was designed to treat runoff from a 1-year, 24-hour storm in southern California. Water enters the structure through a forebay with a 4:1 side slope and a volume of 0.16 acre-ft. This is followed by a wet basin with a permanent pool volume of 0.63 acre-ft, and an average depth of 2.3 feet, which provides an effective 14-day detention time. Water will return to the permanent pool volume within 24 hours of a storm event. The side slopes of the wet basin are 1:6 around the sides and 1:3 from the basin invert to the shallow bench. Water is routed through the basin in a meandering fashion through the use of berms to avoid short-circuiting.

Mosquitofish, *Gambusia affinis*, were stocked in the pond at an initial density of 200 per surface acre for control of immature mosquitoes in the pond. Plant species at the wet basin include various species of bulrush, spikerush, and other marsh and/or aquatic plants that are native to southern California. Some of these plants can grow in water depths up to four feet.

Monitoring Results. Mosquitofish thrived in the wet basin during this study. Fish density remained high throughout the year, and smaller individuals were frequently observed swimming among the stems of the dense shoreline emergent vegetation. Despite the predatory fish, immature mosquitoes were frequently detected in small, isolated shoreline pockets of water among fallen cattails, accumulations of vegetation and plant debris, and algal mats.

Design Recommendations. The biggest concerns associated with wet basins or other permanent water sources are the control of emergent, invasive vegetation such as cattails and sedge as well as the maintenance of mosquitofish populations that keep mosquitoes in check. Wet basins should be designed to reduce the required maintenance and avoid creating vector habitats. Figure 12 illustrates the rapid growth of invasive, emergent vegetation in the wet basin. Dense emergent vegetation causes several problems: 1) it provides predator-free shoreline habitats for mosquito production, 2) it reduces or eliminates access to the pond for routine inspections and/or maintenance, and 3) it can interfere with volume capacity, water flow, and intended water quality benefits. Wet basins should be designed to allow the growth of vegetation only where it is necessary, and to limit the growth of vegetation throughout the remainder of the basin. The following design criteria should be considered:

1. The potential for cattail and sedge growth should be minimized. A minimal constant water depth of four feet or greater will reduce or prevent growth.
2. Side slopes of 2:1 will contain the width or thickness of emergent vegetation to 5 or 6 feet in the basin periphery. This should allow some penetration by mosquitofish and will allow access for vector control staff if mosquito abatement is necessary.
3. The maximum vegetated surface coverage should be 50%. Clumps or islands are preferred. Designs utilizing concrete, rock or liners should be used in areas where vegetation is not desired.
4. For large basins, a launch ramp should be provided to facilitate access for vector control and/or maintenance equipment.
5. A method for water inflow diversion from influent channels and pipes as well as a method for total basin dewatering should be incorporated in the design.

Operation and Maintenance. Regular maintenance of the basin is critical to maintaining a healthy population of mosquitofish. Overgrowth of vegetation and/or decaying vegetation may adversely impact mosquitofish and limit their access to

portions of the basin, while providing attractive habitats for vectors. The following maintenance procedures are recommended.

1. Monthly inspections to determine if and when vegetation control measures are necessary. When emergent vegetation spreads beyond the design parameters, or otherwise contributes to a problem with vector control, it should be promptly removed (or treated with a herbicide where appropriate). It is critical to begin vegetation control actions before the basin is excessively overgrown. Vegetation control may be needed annually, bi-annually, or more frequently as conditions demand.
2. Floating vegetation, such as water hyacinth and primrose, should be controlled monthly by physical removal (or the use of an aquatic herbicide where appropriate).
3. When prevailing winds, or surface currents within the basin, cause an accumulation of vegetation on a portion of the surface, removal should occur more frequently.
4. Outlets and overflow channels should be kept free of debris so surface outflows are not impeded by debris/vegetation accumulations in a portion of the basin.
5. The sediment in the bottom of the permanent pool should be removed every 2-5 years.
6. The presence or intermittent presence of mosquito eggs, larvae or pupae is evidence of mosquito breeding. Control measures should be initiated to supplement the maintenance recommendations already discussed.
    a. Consult the local vector control agency.
    b. Maintain an adequate population of the mosquitofish.
    c. Maintain a residual larvicide in the basin or establish a control plan that utilizes frequent treatments with non-residual larvicides.

Completed June 1999

January 2000

Dense cattail plants. April 11, 2000

Vegetation hand-removal.
August 17, 2000

Rapid vegetation re-growth and colonization.
February 8, 2001

Vector Prevention in Structural BMPs

Figure 12. Wet Basin
(I-5 & La Costa Ave.)

State of California, DHS Vector-Borne Disease Section

Conclusions

This collaborative study provides a preliminary assessment of vectors associated with a number of different structural BMP designs. During the course of the study, VBDS and the four collaborating vector control districts made design and maintenance recommendations that, once implemented, reduced or eliminated habitat previously available for vector production. It is critical that vector control professionals be consulted with regard to BMP design and maintenance to help minimize or prevent vector production. Vector control professionals can provide recommendations based on experience and research that can minimize the potential of structural BMPs to harbor and/or produce vectors. In other cases, local agencies may disapprove of specific designs or structures if they provide excessive habitat for vector species. Proper review of designs to ensure that vector issues have been addressed is necessary. This proactive, rather than reactive approach to the prevention of potential vector problems will ultimately result in cost savings, reduce the need for ongoing vector surveillance and control, and ensure compliance with the California Health and Safety Code. However, it is understood that some structural BMP designs will require ongoing vector surveillance and control.

Stormwater BMP structures are intended to have minimal operational oversight and maintenance, thus it is critical to design facilities in as simple a manner as possible. VBDS and vector control agencies throughout California recommend against the construction of stormwater BMP structures that hold permanent or semi-permanent sources of standing water; however, it is understood that some designs require this for water quality purposes and/ or for proper operation. Operation and maintenance criteria that reduces or prevents vector production should be incorporated into operation and maintenance manuals. Adequate funding for plan review, structure maintenance, and vector surveillance and control activities should be provided for prior to BMP construction. Ongoing cooperation between agencies and others responsible for construction and/or maintenance of stormwater management structures and vector control agencies will be needed to ensure that public health is not compromised.

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