

**Final Vector Report**  
**Caltrans BMP Retrofit Project Sites**  
**Districts 7 and 11**

**September 2001**

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## INTRODUCTION AND BACKGROUND

Over the course of three years, Caltrans developed and implemented a Best Management Practice (BMP) Retrofit Pilot Program in Southern California. The Program included the design, construction, operation, maintenance, and monitoring of BMP pilot projects throughout the urbanized areas of Los Angeles and San Diego counties. An ongoing concern of local public health agencies in these areas has been the potential for vector production posed by these structures.

Structures such as these BMPs can create permanent or semi-permanent standing water and may present opportunities for vectors to establish themselves and potentially spread disease among the general public. It is clear from the BMP retrofit program that existing storm water drainage systems must be modified by adding devices that may contain a permanent pool. Such retrofitting may create opportunities for disease carrying or nuisance organisms to flourish, especially organisms such as mosquitoes that may have to be controlled. Within the loose framework provided by the applicable public health statutes, the BMPs may be viewed as “threats to public health.”

In this situation, several organisms may pose a threat to public health and comfort:

- Mosquitoes are the vectors of primary concern and are the most prominent of the numerous bloodsucking organisms that attack humans. They are the only known means of transmission of the causal agents of several diseases that, in the recent past, have been common in the United States. They require standing water for development, though adults may travel far from such sites in search of a blood meal.
- Black flies are biting flies that inflict a painful bite. Like mosquitoes, only the female takes blood meals. Many humans react adversely to black fly bites. While black flies are important vectors of human disease in the New World and Old World tropics, they do not transmit any known disease to humans living in California. The immature stages of black flies are found in flowing water where the larvae form aggregations on stones, vegetation, debris, and other objects in flowing water. Pupae can be found attached to the larval substrates.
- Cockroaches are considered synanthropic species adapted to living in close association with humans. As such, cockroaches may be encountered in some BMPs that provide habitat and coverage for them. They have never been considered an important vector of disease but are considered a nuisance. The local vector control districts (VCDs) originally requested that Caltrans monitor for these organisms in the BMPs. However, after further consultation, it was determined that these organisms posed little threat to the general population and did not merit inclusion in the general monitoring scheme.
- Midges are small flies that are often mistaken for mosquitoes. Although midges do not feed on blood like mosquitoes, they can become a serious nuisance near wetlands, drainage channels, lakes, golf course ponds, etc. The immature stages of the midge life cycle occur in water. Adult midges are very similar in appearance to mosquitoes and are attracted to lights and to vertical structures, such as the walls of human

residences, adjacent to larval habitats. Midges can be a serious concern near airports where swarms of the flies are attracted to runway lights and can interfere with airport operations. These organisms are included in the monitoring program as both adults and larvae. However, larval midge monitoring is not initiated until sizeable numbers are collected in adult traps.

- Vertebrates that are considered “vectors” are actually “reservoirs” or hosts, and the agents that cause human disease are transmitted by their arthropod parasites. A classic example is plague. The plague bacterium, *Yersinia pestis*, is transmitted to humans by fleas that live on rodents. In California, ground squirrels, chipmunks, and wood rats have also been implicated in the transmission of plague. Other human diseases associated with vertebrates and their parasites are murine typhus, relapsing fever, and Lyme disease. Animals can be true vectors and transmit disease through bites or other close contact. Rabies, for instance, is transmitted when infected saliva enters through a break in the skin. In California, skunks, bats, and foxes are most commonly associated with rabies. Hanta virus pulmonary syndrome is transmitted directly by humans inhaling the virus in feces particles or the urine of deer mice. Other diseases associated with vertebrate vectors in California include tularemia, Rocky Mountain spotted fever, and leptospirosis. Vertebrate organisms of concern for this project are rodents (rats, mice and squirrels), skunks and opossums.

The laws and regulations that govern or relate to mosquito and vector control in California are found principally in the sections of the California Health and Safety Code, Civil Code, Food and Agricultural Code. Health and Safety Code Sections 2270-2294 describe “District Powers.” The Public Health and Safety Code has legal precedence over many other regulations and, presumably, to the court-ordered stipulations that drove the BMP Retrofit Pilot Project. There is legal precedence to support this assertion. Legal opinions regarding issues relating to priority of enforcement for Public Health and Safety Code Sections 2200 and 2292 versus other statutes determined that, with adequate notice, vector control agents had enforcement priority and that other agencies could be held criminally liable for interference with vector control efforts.

## **DEVELOPMENT OF THE VECTOR MONITORING PROGRAM**

In accordance with the Memoranda of Understanding (MOU), DHS staff established comprehensive vector surveillance and monitoring plans for the 37 operational BMP devices conducted in collaboration with the local VCDs in their respective jurisdictions. The primary tasks of the VCDs were weekly monitoring of all BMP study sites for immature stages of mosquitoes and midges. At the same time, DHS 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. DHS also conducted a production study that assessed the actual number of mosquito produced by individual BMPs and BMP types.

There are a total of four VCDs concerned with this project: three in Caltrans District 7 (the Greater Los Angeles County Vector Control District, the San Gabriel Valley

Mosquito and Vector Control District, and the Los Angeles County West Vector Control District) and one in Caltrans District 11 (County of San Diego Department of Environmental Health, Vector Surveillance and Control Section).

### **Service Agreements**

Caltrans initially wished to forge agreements with the VCDs in the form of MOUs. The VCDs within the Los Angeles area had utilized service agreements and MOUs on other projects. Initially, all parties agreed that an MOU would be an acceptable contractual vehicle to enter into. However, it soon became apparent that any MOU between Caltrans and a VCD would be far too cumbersome and could not be formalized and agreed upon in a timely manner. Fortunately, the VCDs would also consider entering into contractual agreements (service agreements) with Caltrans. It became clear that the most expedient arrangement would be that of having agreements between the VCDs and the consultants performing the monitoring and maintenance of the BMPs. The VCDs would in effect be acting as subcontractors to Caltrans consultants and all cost accounting would be centralized under the consultants' umbrella. This decision streamlined the agreement process and would simplify cost accounting.

Entering into MOUs and service agreements was not standard practice for the County of San Diego. The county represented a special case in this instance. Vector control in Los Angeles County is performed by special districts (local VCDs), while vector control in San Diego County is performed by an arm of county government (the County of San Diego Department of Environmental Health, Vector Surveillance and Control Section). Initially, this posed some procedural problems with regard to entering into contractual agreements. Though MOUs and service agreements could not be easily entered into, The county could use a standard service contract that had been previously approved by their Board of Supervisors. The county preferred to utilize the same contractual form when dealing with Caltrans. This arrangement was agreeable to Caltrans. As with the VCDs in District 7, San Diego County entered into an agreement with the consultant (Kinnetic Laboratories Incorporated) in charge of operations and management of the BMPs.

### **Monitoring Roles and Responsibilities**

Agreements between Caltrans, DHS, VCDs and various consultants defined the monitoring responsibilities of each entity. These responsibilities are outlined below.

#### Vector Control Districts/ County of San Diego

The VCDs responsibilities located in the Vector Control Plan (more specifically, the Caltrans BMP Retrofit Pilot Program; BMP Operation, Maintenance, and Monitoring Plan, Volume II, Appendix IV, Vector Control Plan) were limited to the following tasks:

- Monitoring of larval mosquitoes and midges, black fly larvae.
- Visual survey and monitoring of vertebrate vectors (except Los Angeles County West VCD).

- Invertebrate and vertebrate identification.
- Biological and chemical abatement measures (mosquitoes, midges and black flies).
- Data collection for mosquito and midge monitoring and abatement activities.
- Post abatement follow-up monitoring (excluding adult monitoring).

Department of Health Services, Vector Borne Disease Section

The tasks set out for DHS fall under three categories: biological services, engineering services, and administrative services.

- Biological Services - provides Caltrans with expertise and assistance relating to the biological aspects of the vector monitoring and abatement program associated with the BMP retrofit pilot project.
- Engineering Services – provides Caltrans with engineering expertise and assistance relating to the design, operations and maintenance activities associated with the BMP retrofit pilot project.
- Administrative Services – Provides DHS compensation for administrative and management costs related to the activities carried out in the above task orders.

University of California, Riverside (UCR)

UCR collected and identified mosquito and midge adults trapped by routine monitoring at BMP sites and control sites. The purpose of adult monitoring was to determine the relative abundance of potential vectors of pathogens that cause human disease (i.e., adult host-seeking and gravid mosquitoes) and nuisance flies (i.e., biting mosquitoes and non-biting midges). In order to compare post-construction sampling collections with the background (pre-construction) monitoring, UCR made every attempt to ensure that sampling methods were as similar as possible.

The monitoring program was designed to duplicate the trapping efforts included in the background vector/nuisance insect monitoring program carried out during the second half of 1998. The data collected by the post-construction monitoring program permitted comparison of insect abundance before and after the BMP devices were operational.

In order to evaluate the levels of mosquito and midge populations at BMP sites, a monitoring program was undertaken to sample (1) host-seeking adult female mosquitoes by carbon dioxide-baited traps, (2) gravid female mosquitoes by gravid traps, and (3) adult midge populations by light traps. The methods employed were similar to those carried out for the BMP sites before and during construction of the stormwater devices. Larval surveys by dipping were considered the critical component of the post-construction mosquito monitoring program; however, because standing water was not present at the sites prior to and during construction, larval surveys by dipping were not included in the background monitoring program.

Specific monitoring roles and responsibilities of governmental organizations are shown in

Table 1.

**Table 1. Vector Monitoring Roles and Responsibilities for the Caltrans BMP Retrofit Pilot Program**

<b>Caltrans District 7</b>			
	Local VCD	DHS	UCR
Larval Insect Monitoring	✓		
Adult Mosquito Monitoring			✓
Vertebrate Vector Monitoring	✓ *		
Monitoring Coordination		✓	
Vector Abatement	✓		
Data Collection and Management		✓	
Data Analysis		✓	✓
Special Studies		✓	
<b>Caltrans District 11</b>			
Larval Insect Monitoring	✓		
Adult Mosquito Monitoring			✓
Vertebrate Vector Monitoring	✓		
Monitoring Coordination		✓	
Vector Abatement	✓		
Data Collection and Management		✓	
Data Analysis		✓	✓
Special Studies		✓	

\* Vertebrate vector monitoring not performed by Los Angeles County West Vector Control District; performed by DHS.

Vertebrate Vector Consultants

Vertebrate vector consultants were contacted to determine whether proposed BMP Retrofit Pilot Program alterations and additions to existing habitat would significantly increase vertebrate vector activity or undesirable vegetation. These consultants examined all sites prior to construction and made determinations regarding their potential for harboring vectors after construction was completed. Factors considered at each site in determining vertebrate vector potential were:

- Suitability of site and adjacent habitat for vertebrate vector harborage, forage opportunity, water availability, and presence of significant predatory animal populations.
- Suitability of each BMP structure as potential vertebrate vector habitat. Since none of the structures have been constructed, this was accomplished through interpretation of existing engineering drawings and specifications while viewing pre-construction site habitat.
- Determination of probable vertebrate vector species that could reasonably be expected to inhabit each of the proposed BMP sites.

The consultants concluded that it was unlikely that BMP emplacement would increase vertebrate vector harborage or production. Throughout the entire study phase, the presence of vertebrate vectors was never noted.

## **Abatement**

The health code statutes, as written, give district managers wide latitude in determining what constitutes a public health threat. If these statutes are interpreted narrowly, it is conceivable that the mere presence of “open, standing water” could be construed as a threat to public health, and may be abated accordingly. As such, only *prima facie* evidence of breeding (i.e. the presence of only one mosquito larva) is required for abatement. Under these conditions, it is the vector control district managers who largely determine under what conditions abatement will occur.

The vector control districts in Los Angeles County have established an abatement threshold of one larva for the BMPs. With this threshold, these districts can abate when a single larva is collected from a site. The San Diego County Vector Surveillance and Control Division generally does not rely on arbitrary thresholds in determining abatement needs. San Diego County prefers a more pragmatic approach where factors such as BMP location, larval density, and proximity to residential areas are considered.

In order to reduce the production of vectors and nuisance insects and minimize the application of pesticides at BMP sites, effective habitat management is essential. Management strategies should focus on three general areas: physical control, biological control, and chemical control.

### Physical Control

Water management plays a major role in controlling vectors. Standing water should not persist more than three days (72 hours) in any BMPs except for wet basins that require a permanent pool. Even habitat that is only temporarily inundated is capable of supporting mosquito production.

Control of aquatic vegetation is a critical component of controlling vectors in permanent standing water. Vegetation provides refuge from predation and physical disturbance (e.g., waves), and food resources for mosquitoes. Vegetation management also aids in the control of mosquitoes. Standing water that contains vegetation or organic debris is also a problem as they provide ideal egg-laying habitat.

### Biological Control

The biological control agent most commonly used to control mosquitoes is the mosquitofish, *Gambusia affinis*. Mosquitofish are most effective in wet basins that have a depth of 4 to 12 feet and limited shallow shoreline (less than 30 percent of surface area). Their effectiveness as a mosquito control agent declines greatly as the density of vegetation increases.

### Chemical Control

Vector control agencies prefer the employment of new generation biologically rational compounds for mosquito control. These compounds pose an insignificant threat to non-target organisms and are considered the most environmentally friendly approach to mosquito control. Most vector control districts focus on controlling mosquito larvae with compounds such as mosquito-specific bacteria in the genus *Bacillus* and insect growth regulators (IGRs). Control of mosquitoes in the adult stage is rare, and generally occurs only as a last resort.

In Southern California, three types of pesticides are currently used against mosquito larvae: mosquitocidal oils, mosquito-specific bacteria, and insect growth regulators (IGRs).

- Mosquitocidal oil kills mosquito larvae and pupae by suffocation. This oil is the only material available for use in California that is effective against mosquito pupae. The oil dissipates within 48 to 72 hours after application. Mosquitocidal oils are used when pupae are present, or when the conditions are such that other pesticides will be ineffective.
- Mosquito-specific bacterial pesticides are widely used throughout the world for mosquito control. *Bacillus thuringiensis* variety *israelensis* (*Bti*) and *Bacillus sphaericus* are currently registered for use in California. Both *Bti* and *B. sphaericus* are harmless to humans and non-target organisms when applied according to the label directions. The toxins they produce are specific to mosquitoes and degrade rapidly in aquatic environments. The application of *Bti* and *B. sphaericus* to BMPs should not compromise the water quality.
- Insect growth regulators (IGRs) are synthetic hormones that inhibit the development of mosquitoes. When applied to sites where larvae are present, mosquitoes fail to develop into adults. IGRs are available in several formulations including liquid concentrates, pellets, and briquettes, and can also be applied in combination with *Bti*. Methoprene (Altosid) is the most common IGR currently in use with vector control districts in southern California. Liquid formulations of methoprene are currently being used as a regularly part of an integrated control program against mosquitoes in Los Angeles County. Briquette and granule formulations are also available. Briquettes are capable of releasing methoprene over a 30 to 120 day period.

All monitoring and abatement data collected by the VCDs and UCR were transferred to DHS. DHS developed and maintains a central database of all monitoring and abatement data. Abatement actions taken during this study are shown in Tables 2 and 3.

**Table 2. Number of weekly mosquito abatement procedures to BMP structures constructed in Los Angeles County, Caltrans District 7, for the Caltrans BMP Retrofit Pilot Study.**

<b>Weekly BMP Technology Type Abatements</b>	<b>Site Name</b>	<b>No.</b>
<b>Extended Detention Basins (EDB)</b>	I-5/I-605	19
	I-605/SR 91 interchange	0
<b>Drain Inlet Inserts (DII)</b>	Foothill Maintenance Station	0
	Rosemead Maintenance Station	5
	Las Flores Maintenance Station	0
<b>Infiltration Basins and Trenches</b>	Altadena Maintenance Station <sup>a</sup>	0
	I-605/SR 91 <sup>b</sup>	2
<b>Oil/Water Separators</b>	Alameda Maintenance Station	3
<b>Media Filters</b>	Eastern Regional Maintenance	7
	Foothill Maintenance Station <sup>c</sup>	2
	Termination Park and Ride <sup>c</sup>	8
<b>Multi-Chambered Treatment Trains</b>	Via Verde Park and Ride	17
	Lakewood Park and Ride	47
<b>Continuous Deflective Separators</b>	I-210 east of Orcas Ave.	20
	I-210 east of Filmore Ave.	8
<b>Biofiltration Swales and Strips</b>	I-605 Del Amo Ave. <sup>d</sup>	3
	I-5/I-605 <sup>d</sup>	15
	Cerritos Maintenance Station <sup>d</sup>	1
	I-605/SR 91 <sup>d</sup>	3
	I-605/SR 91 <sup>e</sup>	0
	Altadena Maintenance Station <sup>e</sup>	8

<sup>a</sup>Infiltration Trench; <sup>b</sup>Infiltration Basin; <sup>c</sup>Austin-Type Media Filter; <sup>d</sup>Biofiltration Swales; <sup>e</sup>Biofiltration Strips

**Table 3. Number of weekly mosquito abatement procedures to BMP structures constructed in San Diego County, Caltrans District 11, for the Caltrans BMP Retrofit Pilot Study.**

<b>Weekly BMP Technology Type Abatements</b>	<b>Site Name</b>	<b>No.</b>
<b>Wet Basin</b>	I-5/La Costa Ave. (east)	5
<b>Extended Detention Basins (EDB)</b>	I-5/SR 56	6
	I-15/SR 78	0
	I-5 Manchester Ave. (east)	0
<b>Infiltration Basins and Trenches</b>	Carlsbad Maintenance Station	0
	I-5/La Costa Ave. (west) <sup>b</sup>	3
<b>Media Filters</b>	SR 78/I-5 Park and Ride <sup>c</sup>	1
	La Costa Park and Ride <sup>c</sup>	1
	Escondido Maintenance Station <sup>d</sup>	0
	Kearny Mesa Maintenance Station <sup>e</sup>	1
<b>Biofiltration Swales and Strips</b>	I-5/Palomar Airport Rd. <sup>f</sup>	0
	SR 78/Melrose Dr. <sup>f</sup>	0
	Carlsbad Maintenance Station (west) <sup>g</sup>	0

<sup>a</sup>Infiltration Trench; <sup>b</sup>Infiltration Basin; <sup>c</sup>Austin-Type Media Filter; <sup>d</sup>Delaware-Type Media Filter; <sup>e</sup>Canister-Type Media Filter; <sup>f</sup>Biofiltration Swales; <sup>g</sup>Biofiltration Strips

## SUMMARY OF FINDINGS

### Larval Monitoring

In collaboration with the four local VCDs, DHS monitored all 37 structural BMPs at 31 sites in San Diego and Los Angeles counties for mosquito abundance, vegetative cover, predators of immature mosquitoes, physical and chemical properties of water, and evidence of rodent and other vector populations. This information was used to determine which factors within BMPs are most conducive to vector production and which species use these structures. Since mosquitoes are the most abundant and versatile vectors associated with aquatic habitats, this study emphasized mosquito production within BMP structures. The primary tasks of the local vector control agencies included weekly monitoring of all BMP pilot project study sites for immature stages of mosquitoes, midges, and sand flies in their area. At the same time, DHS staff maintained an overall independent surveillance schedule to monitor vegetative cover, predators of mosquito larvae, certain physical and chemical properties of water, and evidence of rodent and other vector populations. In addition, a single vector abatement regimen was prepared by VBDS and implemented by the collaborating vector control agencies. After evaluation of various mosquito larvicides, a liquid formulation of the IRG methoprene (Altosid EC<sup>®</sup>: a juvenile hormone mimic that inhibits successful emergence of adult mosquitoes and a variety of midges) was recommended because of its short residual activity, extremely low environmental toxicity, and negligible effects on larval population dynamics. The local vector control agencies implemented this mosquito abatement procedure as needed.

The primary purpose of this study was to develop a better understanding of vectors associated with different structural BMPs implemented by Caltrans as part of their BMP Retrofit Pilot Study. Two years of larval mosquito data obtained through weekly monitoring beginning in early May 1999 and running through April 2001 are summarized. The data were used to identify vector sources within BMP types or within individual designs and were used to evaluate the success of efforts to mitigate these problem areas.

Eight mosquito species were collected from Caltrans BMP structures during this 2-year study, four of which are known vectors of human disease. Of the nine different BMP technologies implemented by Caltrans, those that maintained permanent sources of standing water (i.e. Multi-Chambered Treatment Trains (MCTT), Continuous Deflective Separators (CDS), and wet basins) provided excellent habitat for immature mosquitoes, and frequently supported large populations relative to other structural designs. In contrast, BMPs designed to drain rapidly (i.e. biofiltration swales and strips, sand media filters, infiltration basins and trenches, drain inlet inserts, extended detention basins) provided less suitable habitats for vectors.

Results showed that vector production at the Caltrans BMP structures was influenced not only by design, but also by factors such as location, immediate and large-scale surroundings, non-storm water discharges (e.g. irrigation), site maintenance, and various

other unexpected events. Because of this, direct comparisons between structures of similar design were difficult, if not impossible. BMP design features identified during this study that contributed to vector production should be avoided in future construction plans. Some examples include the use of any sump, catch basin, or spreader trough that does not drain down completely, loose rip rap, pumps or motors that "automatically" drain water, and effluent pipes with small diameter metering holes that may be prone to clogging. If absolutely necessary, sumps should be covered by a suitable mosquito net that is inspected and replaced on a regular basis. Permanent ponds will always be the source of some vectors regardless of design. To minimize vector production, ponds should be stocked with mosquitofish and be constructed with steep banks to reduce potential breeding habitats (although steep banks may hinder the ponds pollutant removal effectiveness) (the steep slopes are contrary to pond design, OK to leave here, but should we note this). Although shallow pond grades and emergent vegetation increase water quality benefits, steep banks would reduce potential vector sources and vegetation density, benefiting long-term water quality and vector control.

### **Adult Monitoring**

An adult monitoring program was carried out to determine the abundance of pathogen vectoring and nuisance flies at the Caltrans Stormwater BMP Retrofit Program sites in Los Angeles and San Diego counties before and during stormwater device operation. The monitoring program consisted of two components: (1) a background monitoring program carried out during the second half of 1998, before the BMPs were fully operational, and (2) a post-construction monitoring program carried out after construction was completed at the majority of sites. Post-construction monitoring began in January 1999 and terminated on the last week of June 2000. Adult host-seeking mosquitoes (i.e., female mosquitoes potentially biting humans), gravid mosquitoes (i.e., female mosquitoes ready to lay eggs), and non-biting midges were collected using two types of traps: (1) carbon dioxide-baited, UV light traps and (2) gravid traps.

There were no significant differences in the abundance of host-seeking mosquitoes and midges at stormwater BMP sites in July - December 1998 versus July - December 1999; however, several sites showed increased gravid mosquito activity during 1999. This comparison of pre- and post-construction adult mosquito activity is for a period of relatively little precipitation and, consequently, most storm water BMPs should not have contained standing water during much of the annual period of greatest mosquito activity in 1999. Also, any differences that might have occurred due to vector production from the sites would have been lessened because of the control efforts focused on the immature mosquitoes.

Mosquito abundance at "control" locations was significantly lower than at paired storm water BMP sites, particularly media filters, for 50 to 75 percent of comparisons. The number of host-seeking or gravid mosquitoes collected at sites that were designated as "controls" was never significantly greater than the abundance of mosquitoes at paired

storm water BMP sites during July through December 1999, during a shorter, but comparatively wetter, period from May through early July 1999, and during spring 2000.

Activity of mosquito populations was generally low, and did not differ consistently for a particular storm water BMP design in comparisons across all sites. Averaged across sites, host-seeking activity was less than two individuals per trap night and gravid activity was less than 15 individuals per trap night. Gravid mosquitoes may provide a better measure of vector activity than do host-seeking mosquitoes because overall gravid mosquito activity was 10 to 13-fold greater than host-seeking activity at most of the trapping sites. Mosquito activity at the wet basin increased over time and was probably associated with increased coverage by emergent vegetation. Gravid mosquito activity also increased markedly following the installation of CDS units. Design features that permit standing water in storm water BMPs which otherwise would not hold water for more than 72 hours (i.e., energy dissipators or level spreaders at bioswales and biostrips) will also produce mosquitoes and elevate mosquito abundance above the natural background levels.

Adult midge activity at storm water BMP sites did not increase significantly above the background levels that were present prior to operation of the storm water BMP retrofit devices. This observation suggests that none of the storm water devices was producing significant numbers of chironomid midges.

## **Design and Operations Recommendations**

Mosquito abatement is an important concern in much of Southern California because the climate is amenable for much of the year to mosquitoes and the diseases that they transmit. The increasing human population and the addition of water to a historically dry region creates a situation conducive for disease transmission by mosquitoes. The mosquitoes that utilize natural sources such as ponds and wetlands are capable of transmitting diseases to humans. Any new, manmade habitat that might produce large numbers of mosquitoes is a concern to the public agencies charged with vector control.

### ***VCD Recommendations***

The VCDs were initially given the opportunity to provide input regarding the design and maintenance of the sites or structures as it relates to vector control. Much of this input is evident in Appendix IV of the OMM plan. However, they also provided recommendations that may not be self-evident in the OMM plan. These observations and recommendations are synopsized below:

- One of the more effective environmental controls for vegetation, and consequently mosquitoes, is proper water management. Standing water that contains vegetation or organic debris is typically a problem, but habitats that are temporarily inundated can also create mosquito problems.

- Vector control strategies should concentrate on physical measures, minimizing the amount standing water present in the devices. Standing water that persists for three days (72 hours) or longer, especially during warm periods, is likely to produce adult mosquitoes.
- Access to some BMPs will be provided through manholes or grates; vectors will readily enter and exit the structures. Any access cover should be free of apertures large enough to allow entry of adult mosquitoes if a permanent pool of water is maintained in the structure.
- Mosquito production is strongly associated with vegetation densities and coverage. BMP designs that support reduced vegetation growth are preferable for the enhancement of vector control. From a vector control viewpoint, the negative attributes of thick vegetation outweigh many of the benefits. Thick vegetation and inadequate access hinder mosquito abatement. In addition to providing habitat for mosquito larvae and resting sites for adult mosquitoes, thick vegetation will inhibit the application of larvicides.
- If a given site does not drain, heavy equipment used for vegetation maintenance might compromise the integrity of the site by channeling water flow and creating additional habitats (e.g., tire tracks, unevenness in the basin floor that would lead to standing water) for vectors of disease. Scheduling vegetation maintenance as near as possible to the onset of mosquito season (early April) is advisable. Doing so will limit the vegetation in the basin to the greatest extent possible once mosquito populations are likely to increase in the spring. Even though climatic conditions are potentially favorable for year-round growth, some senescence and slowed growth of the vegetation will occur during the winter months. If necessary because of basin characteristics or permit considerations, the vegetation management could be carried out in the late autumn or early winter.
- Vegetation removed from the site will need to be transported elsewhere for disposal. Allowing downed vegetation to remain on site and then inundated may create a severe vector problem.
- Infiltration ponds may be an even greater vector control and vegetation management problem than are detention basins because they encourage the development and accumulation of vegetative detritus that upon re-inundation is attractive to egg-laying mosquitoes and provides resources for mosquito larvae. These sites encourage the growth of vegetation, yet infiltration considerations necessarily limit vegetation management practices.
- Biofiltration swales and strips are intended to serve as filter-conduits to move water from impervious surfaces to other holding structures or the receiving water. As long as standing water does not occur in the swales, the slopes of the designs and the short water residence time should prevent a vector problem. Bacterial degradation of grass

clippings can be highly attractive to gravid (egg-carrying) *Culex tarsalis* and *Cx. quinquefasciatus*.

- If the site does not dry, heavy equipment used for vegetation maintenance might compromise the integrity of the site by channeling water flow and creating additional habitats (e.g., tire tracks, unevenness in the basin floor that would lead to standing water) for vectors of disease. Efforts to maintain the integrity of the basin floor should be maximized.
- Scheduling vegetation maintenance as near as possible to the onset of mosquito season (early April) is advisable. Doing so will limit the vegetation in the basin to the greatest extent possible once mosquito populations are likely to increase in the spring. Even though climatic conditions are potentially favorable for year-round growth, some senescence and slowed growth of the vegetation will occur during the winter months. If necessary, because of basin characteristics or permit considerations, the vegetation management could be carried out in the late autumn or early winter. Vegetation removed from the site will need to be transported elsewhere for disposal. Allowing downed vegetation to remain on site and then inundated will create a severe vector problem.

### **Department of Health Services Design Recommendations**

As part of their engineering design review task, DHS was asked to address design features and other factors that created suitable habitat for the propagation of vectors within BMPs and provide corrective or preventative recommendations for future designs. Their study provides an initial assessment of design criteria related to vector production within BMP structures.

#### General Design and Maintenance Recommendations

Mosquitoes were found to be the most significant and persistent vectors associated with BMP structures that retained a permanent pool of water between storm periods. Because of this, recommendations focused primarily on preventing standing water, which is needed for the development of immature mosquitoes.

As a general recommendation, all BMP structures should be easily and safely accessible (e.g. avoid structures with confined space) to allow vector control personnel to effectively monitor and, if necessary, abate vectors. As a general rule, mosquito larvicides are applied with hand-held equipment at sites with small footprints and with backpack or truck-mounted high-pressure sprayers at sites with large footprints. The effective swath width of most backpack or truck-mounted larvicide sprayers (liquid or granule) are 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, open 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 also important that no vegetation or other obstructions be present

between the access road and the BMP, which 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 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*

- Structures should be designed such that they do 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.
- 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, which may create mosquito habitats. Structures that do not require pumping should be favored over those that do).
- Designs should avoid the use of riprap or concrete depressions that may hold standing water.
- Distribution piping and containment basins should be designed with adequate slopes to drain fully and prevent standing water.

#### *Systems with Sumps, Basins or Permanent Ponds*

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.

- Structures should be designed with the appropriate pumping, piping, valves, or other necessary equipment to allow for easy dewatering of the unit if necessary.
- 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 that female mosquitoes have access to only a limited surface area of water for egg-laying.
- Permanent ponds should maintain water quality and quantity sufficient to support surface-feeding fish such as mosquitofish, *Gambusia affinis*, which feed on mosquito larvae.
- Permanent pond shorelines should be accessible to vector control crews for routine monitoring 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).

- If possible, permanent ponds should be maintained with depths in excess of four feet to preclude invasive emergent vegetation such as cattails. Pond edges below the water surface should be fairly steep and uniform to discourage dense plant growth and reduce favorable mosquito habitat.
- Riprap or liners should be used in areas where vegetation is not necessary, to prevent unwanted growth.
- Permanent ponds should be designed to allow for easy dewatering of the basin when needed.

## **Recommendations for Specific Treatment Technologies**

These observations and recommendations deal with specific design factors of each BMP type employed.

### *Biofiltration Strips and Swales*

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).

### *Austin-Type Sand Media Filters*

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.

- 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.
- It is critical that design plans, particularly hydraulic grades, are carefully adhered to during construction. The design slope of 0.1percent 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.
- 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 hours.

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. Failure to remove and replace clogged sand media will result in inadequate filtration rates and ponding of water in the vaults.

#### *Multi-Chambered Treatment Trains (MCTT)*

Because of the frequency and density of immature mosquitoes detected in the MCTT sedimentation vaults during the study, numerous changes were proposed or made. 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:

- All covers should be constructed to as to seal the units.
- 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.
- 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. Vents for the basin were covered with a fine-mesh screen. No mosquitoes have been detected since the covers were installed.

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 biggest factor contributing to mosquito production was that the sedimentation vault held water continuously. In an initial attempt to mitigate this, the sedimentation vault was pumped out annually 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 replacement of all mosquito screens are necessary. The effectiveness of the MCTT covers in preventing entrance and/or egress of mosquitoes has yet to be fully ascertained.

#### *Canister-Type Media Filter*

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

- The sediment catch basins should not hold permanent standing water. They should be designed to drain down within 72 hours or less.
- Flow spreaders in the canister filter vaults should be designed to eliminate standing water.
- 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.

#### *Delaware-Type Sand Media Filter*

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.

- 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.
- The sedimentation vault should be designed to drain down within 72 hours or less to prevent standing water. The slope of the sedimentation vault should be increased to allow for proper and complete drainage when necessary.
- 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 spring-loaded covers to improve access for maintenance and vector monitoring.

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. Proper and timely

removal of sediment and debris from the sedimentation basin is necessary to prevent standing water and the production of vectors that utilize "muddy," dark habitats for reproduction, particularly sand flies. 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.

#### *Extended Detention Basins (EDB)*

With the exception of the I-5/SR 56 site, 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.

- Avoid the use of sumps that hold water. The sump at the south end of the I-5/ 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.
- Avoid the use of loose-rock rip rap. Mosquitoes and other vectors are highly attracted to protected aquatic habitats. The I-5/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.

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 removed at least once per year.

#### *Infiltration Basins/Infiltration Trenches*

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.

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.

#### *Continuous Deflective Separators (CDS)*

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.

- 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.
- 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.
- 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.

- 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.
- 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.
- 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-storm water discharges.
- An alternative that may be considered is the inclusion of weep 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 weep holes should be incorporated into the design.

To prevent mosquito production during the summer months, water was pumped from the units in late May and taken offsite 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.

### *Oil/Water Separators*

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

### *Drain Inlet Inserts*

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 flow during storm events. Immature mosquitoes were detected in the Fossil Filter™ flume at Rosemead MS on several occasions. 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*

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.

The biggest concerns associated with wet basins or other permanent water sources are the control of emergent, invasive vegetation such as cattails and sedges 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. 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 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:

- 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.
- 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.
- The maximum vegetated surface coverage should be 50 percent. Clumps or islands are preferred. Designs utilizing concrete, rock or liners should be used in areas where vegetation is not desired.
- For large basins, a launch ramp should be provided to facilitate access for vector control and maintenance equipment.
- 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.

Regular maintenance of the basin is critical to maintaining a healthy population of mosquitofish. Overgrowth of vegetation 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.

- 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.
- Floating vegetation, such as water hyacinth and primrose, should be controlled monthly by physical removal or the use of an aquatic herbicide where appropriate.
- 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.

## **LESSONS LEARNED**

The primary purpose of the vector component to the Caltrans Retrofit Pilot Study was to develop a better understanding of vector breeding associated with different structural BMPs. Two large scale studies were performed by the California Department of Health Services: a study that determined mosquito production within the BMPs and a design review of our retrofit BMPs to determine what factors in design are conducive to vector breeding. Because mosquitoes were the most persistent of all possible vectors identified, efforts and conclusions are focused on them. Over the course of two years, results showed that vector production at the Caltrans BMP structures were influenced not only by design features, but also by such diverse factors as location, near- and far-field land use, non-storm water discharges (e.g. irrigation runoff), site maintenance, and various other unexpected events.

The most important lesson Caltrans has learned with regards to designing structural BMPs was to design structures and devices with a drain time of no more than three days (72 hours) for those devices that hold water for any period of time. Mosquitoes require standing water to lay their eggs; therefore, if standing water persists for longer than three days within a BMP, the possibility that mosquitoes will develop successfully increases substantially. If and when a drain down time of three days is accomplished, mosquito breeding should be reduced to negligible levels.

Regular maintenance plays a large part in determining that BMPs drain at their designed rate. Before installation, a maintenance plan should be developed and adhered to ensure outlets are clear of debris and blockage. At the outset of the Retrofit Pilot Program, maintenance on these devices went above and beyond normal maintenance thresholds

and resulted in increased additional costs; consequently, some devices appeared to be cost-prohibitive. Regular maintenance should be cost-effective, and to this end, could be construed to be on an annual, semi-annual, or quarterly basis, dependent on the threshold met. Based on these ideas, a new maintenance plan was approved by Caltrans in cooperation with the plaintiffs, which includes the revised maintenance schedules of annual, semi-annual, and quarterly inspections for various BMPs.

Although designing devices with a short drain times would be the most important preventative measure, there are other factors that could also prevent breeding in these structural devices. It is suspected that location and land use also play a part in determining the frequency and level of breeding. For example, an extended detention basin lies adjacent to a natural wetland in the I-5/SR-56 interchange in San Diego. This wetland, according to the local vector control district in that area, already provide breeding habitat since it naturally contains permanent standing water. Even though there were instances in which breeding was found within the BMP, it would be impossible to show that the BMP provided the habitat (the small pockets of standing water located inside the rock rip rap) to substantially increase the mosquito population of the site. There exists the strong possibility that larvae found could be the result of mosquitoes traveling from the adjacent wetland. The increased amount of habitat provided by the BMP is negligible compared to the habitat area provided by the nearby wetland. All other detention basins in the San Diego area within the program have not shown any evidence of breeding. Additionally, land-use type is suspected to contribute to mosquito breeding. There are two CDS installations located off the I-210 freeway, separated by a few miles; however, one unit (by the Orcas exit) consistently breeds when there is water in the sump while the other unit (by the Filmore exit) breeds far less regularly. This may be the result of horses that exist in the surrounding area. Horses are competent vectors of diseases. At the CDS installation located near I-210 and Orcas, several horses are stabled directly adjacent to the unit; conversely, at the I-210 and Filmore installation, there are no horses that lie in close proximity. These are just a few examples that provide justification for the theory that location and land use may play an important role in determining breeding within Caltrans BMPs.

After two years of larval monitoring and adult monitoring, results show that designing these BMPs with a three-day draw down time is important to the prevention of breeding. Additionally, regular scheduled maintenance is needed to maintain the performance of the devices, and when performing siting studies for these devices, it's important to realize that the surrounding area and land-use may play a part in contributing to the mosquito breeding.