STORMWATER BEST MANAGEMENT PRACTICES, MOSQUITOES, AND WEST NILE VIRUS

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West Nile Virus

West Nile Virus is a mosquito borne disease, a flavivirus commonly found in Africa, West Asia, and the Middle East. Prior to 1999 the virus was predominately found in the eastern hemisphere. In the fall of 1999 an unusually high number of birds were reported dying in the New York City area. The death of the birds was later attributed to the West Nile Virus (WNV).

The virus traveled south along the coast to Florida; it rapidly traveled westerly across the United States to the Midwest. The virus was first identified in Colorado during the late summer of 2002, identified first in horses and birds. By winter it was identified in birds, horses and mosquito pools all along the eastern portions of the South Platte River and Arkansas River Drainages. In 2003 Colorado saw a significant increase in WNV activity, leading the nation in human cases. In that year, Colorado had a total of 2947 human WNV cases with 61 deaths reported (as of 3/31/04). There were a total of 9858 human cases in the U.S. in 2003 with 264 deaths (as of 3/31/04).

It is estimated that 20% of the people who become infected will develop West Nile fever. Symptoms include fever, neck stiffness, headache, body aches, occasional skin rash on the trunk of the body, swollen lymph gland, muscle weakness and paralysis. It is estimated that 1 in 150 persons (<1%) infected with West Nile Virus will develop a more severe form of the disease. More severe infections known as West Nile meningitis and West Nile encephalitis include headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, and convulsions. West Nile infections primarily occur in the human population in late summer and early fall.

The most common exposure route of human infection with West Nile Virus is through the bite of an infected mosquito. Recent investigations have identified blood transfusion and transplanted organs as a source of infection. There is one case of transplacental transmission of West Nile Virus in a human case, and based on a recent case in Michigan, it appears that WNV can be transmitted through breast milk.

Birds are the reservoir host of West Nile Virus; mosquitoes are the vectors for the virus. A mosquito becomes infected when it takes a blood meal from a bird infected with West Nile. The mosquito then becomes infected and may feed on an uninfected bird essentially affecting the bird with the virus. This cycle will take place throughout the summer building up the virus in the bird and mosquito population. Eventually a mosquito will feed on a human incidental host. It only takes one bite from an infected mosquito to transmit the virus to a human. A mosquito cannot become infected from biting an infected incidental host.

It is only the female mosquito that transmits the disease (male mosquitoes feed primarily on plant serums). Female mosquitoes require a high protein meal for reproduction purposes, so they depend on a blood meal to reproduce eggs.

Not all mosquitoes are capable of transmitting WNV; *Culex* species are most responsible for the spread of virus. *Culex pipiens* is a key species in the eastern part of United States, this particular species predominately feeds on birds. In the western part of the United States the *Culex tarsalis* is most responsible for spreading the disease. The *Culex tarsalis* feeds primarily on mammals and is much more efficient transmitter of the virus. Colorado has both *Culex pipiens* and *Culex tarsalis* species of mosquitoes.

Surveillance programs are key in identifying the presence of West Nile. In 2003, the Tri-County Health Department surveillance program consisted of; mosquito, bird, horse, sentinel chicken, and human surveillance. West Nile Virus was identified in 58 mosquito pools, 109 birds, 62 horses, and 409 humans. It identified the presence of the virus in early July. The virus movement was tracked and identified throughout the summer and into the early fall.

It is widely recommended that the best programs for controlling West Nile Virus is through integrated mosquito management, removal of breeding places, and public education. An integrated mosquito management program focuses on interrupting the mosquito life cycle. The best approach is interrupting the mosquito life cycle at the early stages of development of the mosquito larva. This can be most effectively done through water management or use of biological controls. Fish and frogs can play a key role in naturally controlling mosquito larva by feeding on them. *Bacillus thuringiensis* (Bti) is the naturally occurring bacterium that is most widely used for mosquito control. It is commonly found in soil and water. Mosquito larva is attracted to Bti as one of their major food sources. The Bti attacks the mosquito gut causing it to bleed to death.

Another method of control is through the use of growth regulators that prevent the development of the larva onto the adult stage. Growth regulators are chemical products.

Mosquitoes have four stages of their life cycle. The first three stages are egg, larva and pupa of which all are aquatic. The final stage is the adult stage, it is here where transmission of the virus begins. So it is easy to see that control of the virus is key at the larval stage.

Mosquitoes depend on standing water for reproduction purposes. Fluctuating shallow water with vegetation is preferred. Fluctuating water levels affect plant growth by killing some plants. The decomposition of plants promotes bacterial growth of which the mosquito larva depends on as its primary food source. Mosquito larva can complete its aquatic life cycle in as short as 4 days depending on the water temperatures and food supply available to them.

Stormwater Best Management Practices and Mosquitoes

To determine the extent to which stormwater best management practices (BMPs) contribute to the breeding or production of mosquitoes, Tri-County Health Department (TCHD) reviewed the literature and the mosquito control efforts conducted by Adams, Arapahoe, and Douglas County mosquito control personnel in 2003. TCHD also visited several of the BMPs that required treatment during the 2003 season, to investigate why they may have produced mosquitoes.

NATIONAL EXPERIENCE

In 1998, the California Department of Health Service's Vector-Borne Disease Section (VBDS) conducted a two-year study of vector production associated with 37 operational stormwater best management practices (BMP) structures in Southern California. (1) The VBDS surveyed 150 agencies in 289 states. The results of the investigation left no question that a variety of vector species, particularly mosquitoes, utilize the habitats created by stormwater BMP structures throughout the US (1). Of 72 agencies that completed the VBDS questionnaire, 86% reported mosquito production associated with local BMPs. BMPs that maintained permanent sources of standing water provided excellent habitat for mosquitoes and frequently supported large populations. Conversely, BMPs designed to drain rapidly provided less suitable habitats and rarely harbored mosquitoes. (1)

The VBDS study concluded that two factors contribute to mosquito production in BMPs

- Improper design
- Lack of maintenance

The study states that designs that allow water to stand in the BMP for more than 72 hours will allow mosquitoes to breed. Lack of maintenance allows the accumulation of vegetation, silt, and debris that contribute to standing water that remains in the BMP long enough to produce mosquitoes.

LOCAL EXPERIENCE

Arapahoe County

In 2003, Arapahoe County treated 23 BMPs for mosquitoes. This effort required 790 pounds of larvicide and 254 person hours to complete the task. It is estimated that there are a total of 335 to 365 total private stormwater BMPs. On this basis, approximately 6-7% of the BMPs have been found to be problems for mosquito production.

Adams County

In Adams County, it is estimated that 10,000 BMPs were inspected for mosquito production from 1999 to 2003. Of those, 2050 BMPs were treated for mosquitoes. On this basis, approximately 20.5% of BMPs were discovered to be problems for mosquito production in Adams County.

Douglas County

Douglas County treated 168 sites associated with engineered storm drain systems in 2003. The data provided did not make a distinction between stormwater retention facilities and storm drain systems.

Field Investigation of BMPs Associated with Mosquito Breeding

To attempt to determine what aspects of stormwater BMPs may have contributed to mosquito production during the 2003 season, Tri-County Health Department visited several BMPs that Arapahoe County treated for mosquitoes in 2003. Tri-County Health Department was not able to obtain design drawings for the facilities, to determine the exact type of BMP that was initially designed and constructed.

Site 1 was a large BMP, with substantial amounts of wetland type vegetation throughout the entire basin. Standing water was also noted throughout the basin. Concrete culverts at the north and south ends of the basin were surcharged with water nearly to the crown of the pipe. No outlet structure was apparent in the basin. Considering that there was no outlet structure and that significant wetland vegetation was present, it is possible that the facility could have originally been designed as a wetland BMP. The Arapahoe County inspector did mention that a concrete “trickle channel” was on the bottom of the basin.

The presence of the trickle channel would suggest that this BMP was not intended to be a constructed wetland BMP. The presence of standing water in the inlet or outlet culverts indicates that the pipes are completely surcharged with water, providing additional mosquito habitat. In addition, the inundation of the culverts and the trickle channel indicate that this BMP is holding significantly more water than the designers intended.

Figure 1 below illustrates the standing water and lush wetland type vegetation. Figure 2 shows the culvert pipe surcharged with water.

Figure 1: Wetland Vegetation and Standing Water

Figure 2: Concrete Culvert-Nearly Full of Water

Site 2 was an extended detention basin (EDB) that was full of water during the 2003 mosquito season. As indicated in Figure 3 below, the EDB was dry when the photo was taken on March 11, 2004.   The photo shows a very short distance between the inlet culvert and the release structure. It is not clear whether this EDB was designed with a micropool, or if the micropool area had silted in.   The lack of a clearly defined micropool with steep banks can contribute to mosquito production during periods of runoff. In addition, the rock around the outlet may have silted in, preventing the pond from draining between storm events.

Figure 3: Extended Detention Basin

Site 3, in Figure 4 below, was another Extended Detention Basin.   The inlet is shown on the left at the rip-rap. Standing water is noted near the inlet, and the continuous presence of water has created a lush vegetative growth conducive to mosquito production.

Figure 4: Estended Detention Basin, with "Permanent Water" and Wetland Vegetation

Site 4 was another EDB. As shown in Figure 5, the area where the "micropool" would be expected was possibly too "silted in" to allow the micropool to form.

This BMP was equipped with an access road to make it accessible to maintain by periodically removing silt accumulation near the outlet structure. This BMP also had rock around the outlet pipe, that may tend to clog with silt.   The possible “silting in” of the micropool, combined with clogging that may result from the rock at the outlet results in shallow standing water from storm events that remains long enough to allow mosquitoes to breed.

Figure 5: EDB with Access Road and Rock Around Outlet Structure

The outlet structure at Site 5 is shown in Figure 6 below. The photo illustrates significant clogging of the outlet structure that can lead to mosquito production. The micropool no longer exists as it was designed and shallow standing water remains long enough for mosquitoes to breed.

Figure 6: Outlet structure with heavy siltation, preventing drainage

Site 6 is shown in Figure 7 below. This micropool. appears sufficiently shallow and has sufficient stagnant water with organic matter to produce mosquitoes. The rock at the outlet is prone to clogging.

Figure 7: EDB with Micropool & Rock Outlet

Figures 8 and 9 below are from Site 7. Figure 8 indicates two primary conditions for mosquito breeding: 1) permanent, stagnant, standing water; and 2) heavy vegetation that produces organic matter.

Figure 8: EDB? With Permanent Standing Water and Wetland Vegetation

Figure 9 shows an outlet structure at Site 7. It is apparent that the outlet structure does not release sufficient water to have prevented this BMP from becoming a large wetland. This site has produced large numbers of mosquitoes for many years.

Figure 9: Outlet Structure of Perforated CMP Culvert

Figure 10 below is from Site 8. It is unclear whether the standing water shown in Figure 10 was intended to be a micropool or a forebay. The inundation of the culvert does not appear to be intended. Although this BMP was implicated in the production of mosquitoes in 2003, it does appear that it has the potential to produce mosquitoes.

Figure 10: EDB-Not a mosquito site in 2003, but has potential!

Conclusions

Based on a review of literature, data from Adams, Arapahoe and Douglas Counties, and a field tour of known mosquito breeding sites, Tri-County Health Department has drawn some preliminary conclusions. It is established that stormwater BMPs can and do breed mosquitoes. Poor design and performance of outlet structures, appears to be a significant factor causing water to stand in the BMPs for long periods of time. Outlet structures designed with rock around the outlet pipes are prone to clogging with silt. From observation of EDB's, it appears as if the silt first clogs the rock outlet structure. As additional silt enters the BMP, it begins to fill into the micropool basin. The micropool basin becomes shallow, making it favorable for mosquito production. Additional water entering the BMP then "spreads out" beyond the micropool, creating additional mosquito breeding habitat.

It also does not appear that all micropools create habitat for mosquitoes. Micropools designed and maintained with steep sides and deeper pools without vegetation do not appear to breed mosquitoes. These only appear to become a problem when the "rock type" outlet structure plugs from silt and the micropool "silts in".

It has been suggested that many BMPs are initially constructed as construction BMPs, and then are converted to permanent BMPs after completing of grading. During construction, sites are highly devegetated, creating large amounts of silt during storm events that is transported into the BMPs. This silt is often not removed prior to conversion to a permanent BMP, creating a BMP that may hold water well beyond the micropool area for long periods of time. These BMPs may later become "wetlands", due to significant vegetative growth. These factors result in a BMP that can breed mosquitoes, due to shallow, stagnant water that remains for long periods of time and produces vegetation. The vegetation decays, producing organic matter that is conducive to mosquito production.

Recommendations

BMPs should be designed and maintained to drain completely with 72 hours (1). However, it is recognized that many extended detention basins (EDB's) are designed with micropools, i.e. are intended to have permanent standing water. These micropools do not necessarily lead to the production of mosquitoes, if they are properly designed and maintained.

EDBs with micropools can be designed to minimize mosquito production by:

1. Avoiding shallow depths in the pools. Depths should be sufficient to prevent the growth of wetland vegetation.
2. Provide steep slopes to micropool banks
3. Consider mechanical aeration of permanent pools
4. Make the micropool accessible to remove silt, vegetation, and maintain the outlet structure

5. Make the micropool accessible to treat with larvicide
6. Avoid rock at the outlet structures

All BMPs should be inspected during construction to assure compliance with the design. Small design details that are critical to the performance and function of the BMP may be overlooked by the contractor.

BMPs need to be regularly inspected and maintained. Maintenance consists of the removal of silt, and accumulated vegetation, and the outlet structure itself.

Questions for Further Study

During preparation of the presentation and this paper, several questions came up, that require further consideration and study.

1. Is treatment, i.e. larvaciding, less expensive or more cost effective that maintenance?
2. Can counties continue to bear the expense of treating private facilities?
3. If counties cannot afford treatment, can private entities do the job?
4. Are BMPs that become wetlands, subject to Army Corps of Engineers 404 Permits?

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