7 Impact Assessment of the Long-Term Plan

7.1. Introduction to the Analysis Method

The assessment of the impacts of the draft Long-Term Plan is organized by the alternatives selected for analysis, and by the means of conducting the analyses.

Two principal alternatives were considered for the Long-Term Plan:

- a baseline alternative with no vector control at all
- a program utilizing Integrated Pest Management (IPM) techniques to address vector control problems

A preferred methodology of conducting IPM was determined, and alternative approaches were evaluated, including the "no-action" alternative of continuing the current vector control program.

Three types of analyses were conducted for each of the alternatives and comparisons made:

- impacts of mosquito-borne disease
- impacts of pesticides use
- impacts of water management

A discussion of economic and social issues was made separately, and is presented in Section 10. A brief analysis of potential energy impacts is made in Section 11. Solid waste issues were addressed in Section 12.

There were different methods employed to conduct the impact analyses. The mosquito-borne disease analysis was conducted as quantitatively as was possible from aspects of the determinations of WNV and EEE impacts to people. No significant effect from WNV on the environment was determined, and so no assessment of disease impacts to the environment was possible. Projections associated with novel diseases were necessarily qualitative.

The assessments of impacts of pesticides considered for the IPM alternatives were addressed through a complete human health and ecological quantitative risk assessment. The no vector control program option necessarily had no impact from the use of pesticides.

The water management impact assessment was based on qualitative analyses of a series of options. Means for selecting Best Management Practices (BMPs) for any particular setting were outlined. The selection depended on site characteristics, the objectives of the land manager, and the potential for benefits outlined in the assessments. Proper implementation of progressive water management techniques inevitably served to restore wetland functions, and so produced environmental benefits. Options to this nuanced implementation of progressive water management were addressed, in that impacts from applying inappropriate techniques in certain settings were reviewed, and three distinct water management alternatives were also discussed.

These different approaches comprising the assessment were able to identify the IPM approach that should have the greatest benefits and least impacts, and to compare that selected management approach to the no control approach. No control is differentiated from the no-action option, in that the no action option is a continuation of the current vector control program.

SEQRA requires that the no-action option be evaluated. Public concern regarding impacts (and benefits) associated with vector control operations made it clear that a “no Vector Control” option, which is a baseline alternative, needed to be discussed. If mosquito management is to be conducted, the only appropriate means of doing so is utilizing IPM. Since the no-action alternative (continuing the current program) also encompasses an IPM approach, the two alternatives were considered effectively to be:

1. No vector control or
2. Some form of IPM.

Appropriate alternatives were identified, and, if applicable, analyzed separately. For example, the mosquito-borne disease section discussed various mosquito-borne diseases. Therefore, the pesticides impact section did not consider each disease separately, because pesticides address the vector mosquitoes and not the separate diseases. Where cross analysis comparisons were appropriate, the different alternatives were considered.

Some alternatives were considered more likely than others, which allowed for a hierarchical analysis of potential pesticides (using lists of primary and secondary agents). Extensive discussions with advisory groups, consultation with experts within and outside of the technical team, and input from interested individuals and organizations, resulted in the selection of a preferable IPM option to foster the quantitative risk analysis (see Section 4). This management option was called the evaluation management plan, because it was the combination of management choices receiving a full, quantitative risk assessment.

However, the evaluation management plan is not "the preferred option" as, say, defined under NEPA. The derivation of the Long-Term Plan followed the completion of the project-long analysis of alternatives. While the Long-Term Plan was composed of many of the elements of the evaluation management plan, it differs from that choice in key areas, as informed by the risk assessment and other project activities. The Long-Term Plan developed organically as information was developed and acquired over the course of the project, and through consideration of alternative program elements. However, some basic elements of the plan were not affected by this process; the adoption of IPM as a framework for the Long-Term Plan ensures that some elements will be constants. Restrictions are also imposed by regulations.

Alternatives addressed under the determination of mosquito-borne diseases included:

- Conditions under the Long-Term Plan (qualitative comparisons to current conditions)
- Current conditions (quantitative for WNV, semi-quantitative for EEE) and alternates to the Long-Term Plan (qualitative comparisons to current conditions)
- No mosquito control (quantitative for WNV, semi-quantitative for EEE)

In addition, likely novel diseases and their potential impacts for Suffolk County (as measured elsewhere) were discussed qualitatively.

A discussion of potential background pesticides impacts has been presented (Section 3) to inform the pesticides impact analysis. This portion of the analysis reached no firm conclusions regarding the impact of pesticides if vector control applications did not occur. This meant that there is no clear baseline of potential impacts from pesticides.

The quantitative risk assessment on pesticides was conducted on the evaluation management plan. Much of the evaluation management plan background has been presented in Section 4. The quantitative risk assessment depended on model results that estimated potential pesticide exposures under various scenarios. The analyses were developed for four study areas, following the pesticide application scenarios described below. These scenarios were analyzed using three larvicide choices (Bti, Bs, and methoprene) and four adulticide choices (resmethrin, sumithrin, permethrin, and malathion, together with the malathion degradates/contaminants, isomalathion and malaoxon, and the pyrethroid synergist PBO). Garlic oil as a barrier treatment was discussed.

For the pesticide impact section, many of the details in the evaluation management plan were drawn from past and current practices. The overall goal of the Long-Term Plan was to reduce potential human and environmental impacts by reducing pesticide applications. Because the goal is to reduce pesticide use, past practices were used to represent maximal potential application scenarios. However, within this general framework, one major modification was assumed. Early modeling found that off-target drift from aerial applications of adulticides could be reduced through some simple modifications in flight procedures. The problem of suboptimal pesticide application is actually being addressed by the current program through the use of real-time guidance by a linked weather station-pesticide drift model (the Adapco Wingman system).

The evaluation management plan was organized around the four risk assessment areas. The general program of pesticide use was as follows:

- Larviciding: conducted to reduce adult populations of mosquitoes, by a variety of means (hand or aerial applications, including applications to catch basins as well as wetlands). The frequency of applications was determined by statistical analysis of past application rates in the study areas over the 2000 to 2003 time period. Maximal applications in the study areas were modeled.
- Adulticide applications for vector control: conducted to reduce impacts to public welfare and to reduce disease potential from large mosquito populations. The frequency of applications was assumed to be 14 times per year in Davis Park (Fire Island), at one week intervals, using hand applications, and eight truck sprays a year at weekly intervals in Mastic-Shirley, by truck.
- Health Emergency applications: conducted to reduce risk of human disease, following guidance outlined by CDC and NYSDOH. The frequency of the applications was assumed to be twice in Manorville at two week intervals, twice in Mastic-Shirley at one

week intervals, and once in Dix Hills. All of these applications were assumed to have been applied by air.

Pesticide applications were assumed to be those currently in use, with one exception. The Long-Term Plan process had identified modifications to aerial applications that would reduce off-target drift and that could be implemented without difficulty. Because there was no chance that the procedures in use in 2004 would be implemented by the Long-Term Plan, as the 2004 methodology was decidedly suboptimal, the modified method was incorporated into the modeling approach.

The evaluation management plan called for an IPM implementation, based on a hierarchical approach of public education, source reduction, larval control, and only as a last resort, adult control. Scientific surveillance was to be the basis of information needed to make control decisions.

The evaluation management plan contained other modifications from the present practices of Suffolk County. These included improved public outreach, better data management, more emphasis on tire management, more extensive monitoring (with an improved laboratory), efficacy testing for larvicide and adulticide applications, more quantitative information use in adulticide decision-making, and most importantly, incorporation of progressive water management into the program. All of these improvements are expected to have measurable impacts on human health, public welfare, and environmental impacts associated with the Long-Term Plan. However, to ensure a conservative outcome, no benefits were assumed when computing risks associated with pesticide use.

Additional management options were considered. These consisted of the current program and five alternatives to the pesticide program:

1. use Mosquito Magnets in place of adulticides at Davis Park
2. eliminate the use of all larvicides in fresh water environments, and no use of methoprene in salt water settings

3. adulticide only in cases of declared human health emergencies (eliminates all adulticide applications considered under the evaluation management plan except for the aerial applications)
4. adulticide only after human illness
5. eliminate all adulticiding

In addition, qualitative comparisons of risks associated with the Secondary Agents (see Table 4-2) were derived.

The water management segment focused on the proposed adoption of 15 BMPs, and four Interim Actions/On-going Maintenance Options. These constituted the advances proposed to meet the needs of the program to improve environmental quality while preserving or improving human health and public welfare. Three explicit, programmatic alternatives were addressed:

1. adoption of a program allowing only natural processes to occur in the marshes (all reversion)
2. continuation of the present reliance on ditch maintenance as the sole means of water management
3. expansion of ditch maintenance practices so that all ditches in the County are routinely maintained

The impact of changing water management techniques were not completely addressed in the analysis. For example, it might be assumed that progressive water management would produce quantifiable changes in larvicide applications. The Wetlands Management Plan projects approximately 75 percent reductions in larviciding (as measured by acres of marsh treated in a year, in comparison to a baseline of 30,000 acres) to be realized over the next 12 years. The measurement of larviciding extent by application acreage is appropriate, as it will capture reductions in area in individual marshes, as well as decreases in frequency. Using amounts of larvicides applied may not be as reliable, as the formulations of products selected or used may change over time. In addition, progressive water management is assumed to reduce the incidence of mosquito-borne disease by providing more consistent control of vector populations. However, the time period discussed in the water management section was not consistent with a nearly immediate time horizon for almost all parts of the pesticides and mosquito-borne disease sections. Therefore, the benefits associated with adoption of progressive water management (and the impacts associated with the major alternatives to progressive water management) were not factored into the pesticides and mosquito-borne disease sections.

7.2. Introduction to the Long-Term Plan

Mosquito control in the United States has evolved from reliance on insecticide application for control of adult mosquitoes to IPM programs. IPM programs focusing on mosquito control are sometimes referred to as Integrated Mosquito Management (IMM). IPM addresses mosquito problems through a hierarchical application of the following elements:

- Public education and outreach
- Scientific surveillance
- Source reduction/control (water management is a special subset of source reduction)
- Biocontrols (a special subset of larval and adult control)
- Larval control
- Adult control (but only if necessary)

Adherence to the hierarchy addresses mosquito problems so initial responses are limited in scope, but are selected to have the greatest impact at the most effective time, with the fewest environmental impacts. Actions further along in the hierarchy generally require more effort and organization to address, and may have more impacts, because the problem is being addressed in a more general fashion. Because adult mosquitoes are the most dispersed form of mosquitoes, and generally present more pathogenic potential, their control is more difficult and invites more complex solutions that can lead to greater potential impacts and more public concern and controversy. In terms of impacts ranging from costs, environmental effects, control of human disease, and public concern, it is almost always preferred to address a potential mosquito problem through the hierarchy (Rose, 2001).

The Long-Term Plan describes an IPM approach to Suffolk County's mosquito problems. The current approach is also an IPM program; however, the Long-Term Plan has made, in places, incremental improvements to the current approach, and in others has proposed a strikingly different approach.

Determining the impacts of something that has not been implemented is often necessarily speculative. The impacts of current operations may be more concretely described. Therefore, where the Long-Term Plan considers incremental change to current operations, the impacts of current operations have been determined (as best as can be), and presented in this section. The potential changes to those impacts resulting from implementing the Long-Term Plan are then described. Where changes to current operations are more considerable, as with water management, the discussion does not refer to the impacts of current operations as a basis.

7.3. Impacts of the Long-Term Plan: Part 1, Public Outreach And Education

This section discusses the impacts of public education and outreach. It begins by discussing the potential impacts associated with current program and then describes the proposed changes to the current program in the Long-Term Plan, and the impacts that might be associated with those changes.

7.3.1. Current IPM Program

The existing IPM program has a public education program that has three major elements:

- Face-to-face education
- Publications
- Web sites

Face-to-face education consists of two major efforts. One is formal, and is conducted by SCDHS health educators. This is school and community organization outreach, focused around the publications the County uses. Educators respond to requests for information, or sometimes seek to develop audiences in key areas for this outreach. The outreach focuses on the "Dump the Water" and "Fight the Bite" campaigns (see below). A strong emphasis is always made on the steps individuals can take to avoid mosquito bites:

- Maintaining screens
- Avoiding the outdoors at dawn and dusk

- Using DEET or equivalent repellents
- Maintaining home environments that do not foster mosquito breeding

The second face-to-face education element occurs when field crews from SCVC respond to complaints. This can present opportunities, which need to be taken advantage of, for education of homeowners to address any self-inflicted mosquito problems. The focus here is on proper maintenance of a property to minimize breeding opportunities.

There are two primary publications used by the County. One is self-produced – Dump the Water, sponsored by the Legislature. An elementary school contest is used to generate a cover for this pamphlet each year. It describes how WNV is transmitted and what the public can do to eliminate mosquito-breeding sites around their homes, encourages the public to educate neighbors and local business owners, and to become involved with local organizations that have goals suited to mosquito control efforts. It includes local and state contact information.

The second publication is from NYSDOH. The Fight the Bite pamphlet includes information on:

- mosquito species
- where they live and breed
- symptoms of WNV
- who is most at risk of contracting WNV
- when mosquitoes are most active
- what can be done around the house to diminish mosquito-breeding sites.

An illustration is included to demonstrate where typical mosquito breeding sites can be found around the home. The brochure also provides examples on what to do to protect oneself from mosquitoes, how to properly use DEET, and what to do after spotting a dead bird. As with the SCDHS brochure, the New York State publication also includes contact information, although this information is for statewide offices concerned with mosquito control.

The SCDHS website includes information on mosquito control, including adulticide application public notices. There are links from the website to other mosquito control sites such as NYSDOH.

Certain public outreach efforts (other than education) are required under the Suffolk County charter. These include notification schedules for the application of adulticides, and the creation of a no-spray registry. For properties on the no-spray registry, SCVC is required to "make a good faith effort" to exclude each property by stopping adulticide spraying from trucks within 150 feet on either side of a registrant's property. Citizens can sign up for this registry via the SCDPW website, or by calling the SCVC directly.

The effects of these efforts are positive. People who are not exposed to mosquitoes cannot be negatively impacted by them. It appears *Cx. pipiens*, the house mosquito, can be significantly controlled by homeowner actions, and, as the mosquito tends not to travel far, the benefits of household water management are experienced by those who conduct it. *Cx. pipiens* is an essential element in the propagation of WNV, if not the principal human vector. This means there are opportunities to decrease human health risks through the education programs.

Avoidance of mosquitoes, and the use of DEET when exposed to mosquito conditions, appears to provide protection from mosquito-borne disease (NYSDOH, 2001a). However, in some situations, avoidance of mosquitoes requires severe limitations on outside activities. Although most mosquitoes are not active during the day, *Oc. sollicitans* (the salt marsh mosquito) is a very aggressive day biter when disturbed from daytime resting places (often in lawns or open fields). Therefore, if a brood of *Oc. sollicitans* has invaded a neighborhood, there may be times when it is not possible to have peaceful enjoyment of one's yard.

Use of DEET is subject to some controversy. It is not the most aesthetically pleasing topical application, as it is oily, and has a distinct smell (and taste), and has been implicated in certain health issues. The compound DEET (N,N-diethyl-m-toluamide) was first registered as an insect repellent in 1957. It is used to repel biting insects, such as mosquitoes, ticks and flies (USEPA, 2004i), by interfering with the insect's ability to sense or locate animals to feed on. DEET can be used in homes, applied directly on the skin and clothing, and can be used to protect animals (such as dogs, cats and horses). The percentage of DEET in products can vary, ranging from about five to 100 percent (USEPA, 1998d). It is remarkably effective and studies have shown consistent abilities to allow people to share space with mosquitoes seeking blood meals and yet avoid nearly all bites (Fradin and Day, 2002).

Up to 20 percent of a dermal application of DEET can be absorbed through the skin (USEPA, 1998d). It is generally eliminated through urine within several hours, and does not accumulate (Qiu et al., 1998). Use of sunscreens with added DEET enhances absorption (NYSDOH, 2001b).

There have been some reports of seizures in children using DEET products (Oransky et al., 1989). The number of cases of effects appears to be quite small, given broad estimates of 50 to 100 million users each year. USEPA (1998d) concluded that although DEET was implicated in certain seizure cases, insufficient evidence existed to conclude that DEET caused the seizures. Nonetheless, USEPA suggested it is prudent to exercise caution in the use of DEET directly on the skin. There are some indications that long-term use may have some negative effects, although these reports are either from animal studies or anecdotal. Studies of synergistic effects of DEET with other chemicals (from Gulf War Syndrome research) are not conclusive (Gillette and Bloomquist, 2003).

The US Army has found it difficult to ensure that soldiers use DEET as ordered. Compliance rates, even when under orders, have been low as 50 percent. Aesthetic problems, including the feel of the repellent on the skin and its odor, are cited (as well as fears associated with some of the concerns raised above). The Army is now developing its own alternative to DEET (Debboun and Klun, 2005).

Some repellents are said to be "just as good" as DEET. Most do not measure up in independent research (Fradin and Day, 2002). Some that have fared well include:

- BiteBlocker (a botanical product) (Fradin and Day, 2002)
- Picaridin (a European repellent) (recently receiving approval as effective in New York State)
- Oil of Eucalyptus (a botanical also recently receiving approval as an effective repellent)

Citronella has been found to be very effective, despite word of mouth to the contrary (Fradin and Day, 2002). It may be that reactions between an individual's skin/skin chemicals/other applied soaps, perfumes, etc., result in particular combinations that serve to repel mosquitoes. This may account for products that have fierce loyalties, but test poorly. However, for citronella, Health

Canada has raised concerns regarding potential negative impacts to people from use of the material on the skin (Health Canada, 2004). Overall, NYSDOH still recommends the use of DEET (NYSDOH, 2001b).

Public education and outreach associated with current operations appear to reduce impacts associated with mosquito-borne disease, albeit in ways that cannot be quantified. Work in Canada did find significant reductions in WNV risks when residents used two of three personal protection steps (avoiding mosquitoes, wearing long-sleeved shirts and long pants, and applying repellent) (Loeb et al., 2005). However, general compliance rates for such advisories have not been well determined. Some surveys in Louisiana suggest that decision making regarding personal protection is complex, formed by sociological issues as well as scientific and technical education on disease transmission (Zielinski-Gutierrez, 2002). Nonetheless, the outreach program may reduce impacts associated with pesticides applications if various guidances are heeded. There is no element of the current program that addresses water management.

7.3.2. Long-Term Plan

The Long-Term Plan proposes to continue each of the above efforts and to augment them.

Education efforts will be improved through the quantity and quality of information generated by the Long-Term Plan process. In addition, a concrete proposal is for a seminar between SCDHS educators and SCVC field crews to allow for cross-fertilization of ideas, and to discuss what problems each perceives, and what aspects of the programs are working well. These annual meetings should allow each part of the education program to be honed.

Specific elements (and audiences) that are to be targeted include:

- Tire management. This will mostly be internal in the County workforce, to reinforce efforts to clean littered tires by the Parks and Public Works Departments, as a habitat reduction step.
- Farmer irrigation outreach (through Cornell Cooperative Extension). Prevention of standing water on farms has been a long-term SCVC water management element, and this education component will reinforce existing water conservation efforts.

- Private storm water system maintenance (outreach potentially through tax bills). Westchester County had success in reducing *Culex* populations by reminding commercial property owners and private communities that maintaining storm water systems not only reduces flooding, it also eliminates mosquito habitat.

- Public storm water system outreach. To reach the same goal as just above, but to a different audience.

- In addition, those areas (primarily along the south shore) that have historically been the subject of Vector Control adulticide applications will receive targeted public outreach. This outreach will focus on two areas. One is for residents to assume personal responsibility for reducing impacts from mosquitoes, by avoiding mosquitoes whenever possible, and, if exposure cannot be avoided, wearing long-sleeves and pants, and using repellents. Secondly, the Commissioner of SCDHS will issue guidance to reduce potential impacts from exposure to pesticides. At this time, the public notice for adulticide application includes the following language:

> Steps you should take: Children and pregnant women should take care to avoid exposure when practical. If possible, remain inside or avoid the area whenever spraying takes place and for about 30 minutes after spraying. Close windows and doors and turn off air-conditioning units or close their vents to circulate indoor air before spraying begins. Windows and air-conditioning vents can be reopened about 30 minutes after spraying. If you come in contact with pesticide spray, protect your eyes. If you get pesticide spray in your eyes, immediately rinse them with water. Wash exposed skin. Wash clothes that come in direct contact with spray separately from other laundry. Consult your health care provider if you think you are experiencing health effects from spraying.
>
> Steps you may wish to take: Cover outdoor tables and play equipment before spraying or wash them off with detergent and water if exposed to pesticides during spraying. Bring laundry and small toys inside before spraying begins (wash with detergent and water if exposed to pesticides during spraying). Bring pet food and water dishes inside, and cover ornamental fishponds to avoid direct exposure.

The Commissioner may continue this advisory or modify it in some fashion to address some of the findings of the risk assessment and other project efforts.

The publications will be formally increased by the production of the Citizens Advisory Committee brochure. This publication will focus on personal responsibilities for mosquito control, according to a draft, and its non-government perspective should make it a useful addition to the two current publications.

It was also suggested that the County use either the example or the actual output of New York City's multi-lingual capabilities, to allow it to reach the County's diversifying population more effectively.

The materials generated by the Long-Term Plan, while mostly technical and/or academic in content, will also be available to the public.

It has also been proposed that the County's website be improved. Information presented has not been regularly updated (other than the spray notifications). Much of the information from the Long-Term Plan website may be transferable to the County site, for example.

Public outreach efforts will similarly be improved. Major efforts include:

- Participation in "Mosquito Awareness Week," an American Mosquito Control Association (AMCA) sponsored program, at the start of the summer season.
- Efficacy reporting to the public will become a major effort. SCVC is intending to improve its collection of efficacy data, and the results will be made available to the public via the web and annual reports.
- Continuing the Citizens Advisory Committee as a means of having on-going dialog with involved members of the public.
- Continuing various contacts with state, federal, and local agencies and governments, and certain interested non-governmental organizations, that were renewed through the Long-Term Plan process (especially through the Wetlands Advisory Committee and Technical Advisory Committee).
- Create a listserv for adulticide application notifications.

These changes should enhance positive elements of the existing public education and outreach program without any undue impacts. The effort required for these new programs is considerable.

However, the additional work should be accommodated within the proposed personnel enhancements requested for SCVC (mostly for other reasons), and so essentially have no specific impact in and of themselves.

Therefore, the relative impact of the Long-Term Plan should be more positive than the existing Education and Outreach Program, which was also judged to have an overall positive impact. The Long-Term Plan has the potential to reduce impacts associated with mosquito-borne disease more than they are reduced under current operations, albeit in ways that cannot be quantified, and may reduce impacts from pesticides applications if various guidances are heeded and reports referred to. This element does not specifically address water management issues, except by making the Literature Search information available.

7.4. Impacts of the Long-Term Plan: Part 2, Surveillance

This section discusses the impacts of conducting surveillance. It begins by discussing impacts associated with the current program, and then describes the proposed changes to the current program associated with the Long-Term Plan.

7.4.1. Current IPM Program

The current vector control program conducts surveillance in order to describe mosquito populations (population surveillance) and to determine if pathogens are presenting a human disease risk (disease surveillance) (Moore et al., 1993b). Responsibilities for these two aspects of surveillance are approximately divided between SCVC for the former, and the ABDL for the latter. At times these distinctions are not maintained, however. For example, the peak of viral concerns (in August), all personnel assist in the ABDL task of preparing samples for viral analyses (either by RAMP at the ABDL, or by NYSDOH in Albany).

These surveillance methods are based on scientific principles and consistent techniques for sample acquisition, and follow industry standards. The collected samples are processed consistently and expertly, using protocols that are common throughout mosquito programs nationwide. The intent of this care in conducting surveillance is to provide a scientific basis for decision making resulting from the sample collection and processing (Reinert, 1989).

Population surveillance is based on collecting samples of larval and adult populations. Larval samples are acquired from aquatic habitats, either from a set sampling point (a mosquito breeding site), or in response to a logged complaint. Generally, the number of larvae is not important. Presence or absence of larvae, and the species present, are more important. Larval samples can be and often are identified in the field (O'Malley, 1989); results are verified in the laboratory. For some locations, the number of larvae in each sample is important for management decisions, as at Wertheim National Wildlife Refuge.

Adult population estimates are collected either from traps, from anecdotal reports from field personnel (informal landing rates), or from citizen complaints.

Trap population information is gathered from fixed New Jersey light trap locations or fixed and variable CDC light trap locations. The fixed New Jersey trap locations are generally used as area measures of mosquito populations. They are generally sited to provide information regarding broods or other pestiferous accumulations of mosquitoes in areas that have historically had problems. As such, they are used as a measure of mosquito densities over a larger area and as programmatic tests of larvicide and water management efficacy. New Jersey trap data are best used to analyze actions made on an areal basis, not particular ditch maintenance events, or the larviciding of a particular marsh (Reinert, 1989). CDC traps either were specifically located to generate information concerning particular trouble spots, or are set in response to some cue – a dead bird, for example. The distinction is not based on the attractive range of the traps, but that CDC trap placement is more flexible. Trap collections are processed in the laboratory, providing counts and species compositions (McNelly, 1989).

Informal reports from field crews are used in several ways. One is to be the first sign of problems, such as information collected out on the marsh as a brood is hatching. They can be used to confirm the existence of a problem prior to taking action. Reports can establish the veracity of a complaint. They can be used as independent measures of the seriousness and extent of an infestation. These measures are most effective for *Oc. sollicitans* information collection.

Citizen complaints are important surveillance tools, as well. They can define the area of concern for potential action, or to delineate where a known problem exists, and to serve as definitions of the extent of biting problems (Romanowski and Huggins, 1989). For Fire Island, where timely and efficient access is a long standing problem, the mosquito committees serve as auxiliaries for SCVC surveillance, providing consistent and trustworthy reports on the amount and extent of mosquito problems within their communities.

Disease information can be collected directly from mosquitoes, or through many different indirect methods. Direct information collection requires trapping mosquitoes. Two traps can be used. CDC light traps collect night-flying warm-blooded animal-biting mosquitoes, by releasing carbon dioxide as bait, and a light/heat source. CDC gravid traps capture mosquitoes seeking water to lay eggs (this means all of the mosquitoes are parous), and now are most often baited with "polluted" (high organic content) water to attract *Cx. pipiens*. In both cases, the mosquitoes are captured alive, and, if collected and processed with care, can be analyzed for pathogens (CDC, 2003a). Local processing ability includes the capability of testing for WNV, but since that can preclude having the sample tested for other viruses and pathogens, nearly all samples are processed by NYSDOH in Albany.

Indirect methods include collection of dead birds (Edison et al., 2001) (processed both locally and in Albany), and collecting information on unusual illnesses from veterinarians and doctors/hospitals (NYSDOH, 2001b). Many mosquito-borne disease of concern affect important agricultural animals, such as horses, pheasants, and emus. The initial discovery of WNV depended on astute analysis by a doctor in Elmhurst. Malaria was found in Suffolk County in 1999 after it was diagnosed in two boy scouts by a local physician.

The collected information on pathogens can be combined with information on local mosquito populations, including the dynamics of those populations (both as measured and as projected), to make treatment decisions, informing the risk assessment that needs to be conducted with quantitative and scientifically-acquired information (NYSDOH, 2001b; CDC, 2003a).

Surveillance therefore is central to treatment decisions. It determines the initial, potential need for treatment, bounds the areas of concern, and provides the input to form the justification for or against the application of pesticides (or other actions to control mosquito populations).

Such surveillance is essential to the practice of IPM. IPM requires that treatments be commensurate with the problem. Without accurate surveillance, there is no means of determining the scope of the problem, and therefore no means of determining what treatment is best. Because of this central role in grounding the entire process, surveillance must be viewed as an entirely favorable process.

The current approach reduces impacts associated with mosquito-borne disease by allowing prophylactic measures to be taken prior to any disease incidence. It also reduces disease risk by limiting vector populations by determining where incipient mosquito problems may be brewing. Good surveillance reduces the use of adulticides by allowing problems to be addressed more appropriately and earlier. An argument could be presented that surveillance, by identifying problems, causes more pesticide use since otherwise the problem might never have been detected. However, mosquito problems are generally defined by the presence of people. Therefore, surveillance identifies problems using scientific techniques, problems that eventually would be identified through complaint calls from the affected population. Essentially, surveillance drives IPM. The accepted principle of IPM is intervention should be appropriate and early, rather than late. The current approach also allows for appropriate ditch maintenance or culvert repairs (essentially the two forms of water management that are permitted under the existing program) to be conducted, by identifying areas where breeding is occurring. Supervisors can then determine if ditch maintenance can provide a treatment for an on-going problem.

If IPM rationales are accepted, and ditch maintenance is accepted as a means of water management where the benefits exceed the costs, then surveillance as practiced under the current program clearly has human health and environmental benefits. It seems clear that if mosquito management is to be undertaken, an IPM approach must be selected. The discussion regarding how ditch maintenance will be undertaken can be found below, and in Section 8. If ditch maintenance is not accepted as having minimal impacts, then the current surveillance program provides considerable human health benefits with some environmental trade-offs.

7.4.2. Long-Term Plan

The Long-Term Plan seeks to increase surveillance capabilities considerably.

First of all, catch basin sampling and treatment will be increased, with the intent of limiting *Cx pipiens* breeding opportunities. CDC light trap placement will be increased, partially to increase adult population surveillance. Efficacy testing will be implemented (both for larvicides and adulticides). Although adulticide efficacy testing is a goal of current operations, the press of limited resources means it is often foregone. Efficacy testing will be a higher priority issue under the Long-Term Plan.

Disease surveillance will also change. There will be changes in EEE monitoring, in response to reconsideration of the dynamics of that disease, including reassessment of potential amplification loci. It appears likely that dead birds will no longer be as useful as WNV surveillance tools; a major issue for the program will be to determine if another indirect measurement of virus presence can be developed, or whether CDC trapping needs to be increased to meet new surveillance demands. The development of in-house virus testing will continue through the proposed BSL-3 laboratory project; until that is implemented, faster turn around times will be used through NYSDOH to increase the information value of the pool testing.

Staffing for surveillance for both SCVC and the ABDL will be increased, and the division of authority more clearly defined in the laboratory facilities, to allow for efficient gathering and processing of both population and disease information. Data management will also be improved, especially through GIS. Public dissemination of much of the information generated in these programs will also be increased, to justify the program and its control decisions more clearly.

Although this effort will require the commitment of additional resources by the County, including a substantial capital investment for a new, specialized laboratory (the added value to the information used for decision making justifies the cost). Current decision making is done in accord with NYSDOH and CDC guidance, but sometimes relies on qualitative information, or data that is a little older than would be preferred. This requires the professionals within SCDHS and SCVC to exercise their experience and judgment in order to make the best possible decisions. Better surveillance can make the quality of the information better, and so ensure that the professionals have the best possible means of making the best possible decisions for what may be crucial public health situations for the residents of the County.

The Long-Term Plan surveillance program should provide the means of reducing mosquito-borne disease impacts from what the current program is capable of. Improved surveillance may reduce pesticide usage slightly, although that is difficult to forecast. In the case of EEE situations, more complete surveillance may actually lead to more pesticide use, to prevent the disease from impacting public health. Replacing ditch maintenance with a more complete, progressive water management option should mean that surveillance will have, insofar as it promotes effective progressive water management, certain positive environmental effects.

7.5. Impacts of the Long-Term Plan: Part 3, Source Reduction

This section discusses the impacts of conducting source reduction. It begins by discussing impacts associated with the current program, and then describes the proposed changes to the current program under the Long-Term Plan and potential impacts associated with the Long-Term Plan.

7.5.1. Current IPM Program

The current vector control program conducts source reduction primarily through its public education program, responses to citizen complaints, some catch basin and recharge basin control efforts, and through water management. Water management is discussed separately, and not in this section.

Public education is an important component of source reduction as it is the first step in realizing household source reduction. It keeps the public aware of the extreme importance of keeping clear artificial containers, clogged rain gutters, bird baths, and other inaccessible places found around the house of stagnant water as they can become breeding grounds for mosquitoes.

Inspectors and field crews respond to complaints from the public within one to three days of a call. The cause of the complaint is investigated and very often this leads to mitigation of standing water or other breeding conditions at the location of the complainant. Sometimes the investigation results in a larger investigation of some mosquito source away from the residence.

The County has an extensive program to address mosquito breeding in water management structures. On the order of 10,000 catch basins are routinely larvicided annually to control *Culex* breeding. These basins were primarily identified through geographical stratification, as it has been thought that where the water table is high relative to the ground surface, it is more likely for catch basins to hold water. Therefore, SCVC has conducted surveys of such areas, and basins that retain water are treated with the longest-lasting methoprene briquets.

Recharge basins can also be sources of biting mosquitoes. In those cases, field crews can determine if larviciding or treatment with mosquito larvae consuming fish is the appropriate treatment. Stocking *Gambusia*, the mosquito fish, which SCDHS purchases from commercial suppliers, has been an option that has resulted in generally good control where water quality is not totally unacceptable.

The impacts associated with the current public education approach have been discussed above (section 7.3, including impacts associated with educating householders). Benefits to source reduction efforts in water management structures are fairly clear, as *Cx. pipiens* is the primary zoonotic vector of WNV, and uses these habitats to breed in. Recharge basins also support other fresh water mosquitoes. Human discomfort, at a minimum, can be decreased by controlling mosquitoes in these habitats and if bridge vectors are produced, control efforts can reduce risks to human health.

Impacts associated with the use of larvicides in general, and methoprene in particular, are discussed below in Section 7.8. Impacts associated with the use of *Gambusia* will be discussed in Section 7.7.

7.5.2. Long-Term Plan

The Long-Term Plan will increase the coverage of catch basins and recharge basins, but use shorter-lasting treatments when larvicides are applied. The education component will be augmented, including attempting to create a County tire collection effort, adding a private storm water management system outreach effort, and trying to increase the amount of interaction between SCVC and highway departments (including County highway managers) for storm water management cooperation.

Tires are replacing tree holes as a preferred breeding environment for certain mosquitoes. Tires always have a "down" side in which water can collect, and are impervious, so that the collected water must evaporate to remove potential habitat. The mosquitoes using tires to breed in include some of the more aggressive human biting species, such as *Ochlerotatus japonicus* and *Ochlerotatus triseriatus*. Both are known vectors of WNV. *Oc. triseriatus* is also known as a vector of La Crosse virus, although that encephalitis is not found in Suffolk County. *Oc. triseriatus* transmits La Crosse virus vertically, that is from mother to daughter. Especially severe outbreaks tend to cluster, which suggests that a particularly virulent strain may be transmitted through generations at a local breeding point, such as a small tire dump (Kitron et al., 1997). *Aedes albopictus*, another treehole-tire breeding mosquito, was introduced into the US recently from Asia (as was *Oc. japonicus*). *Ae. albopictus* has not yet been found in Suffolk County, although it has been trapped in Nassau County. *Ae. albopictus* is the major Asian vector for Dengue, although Dengue has not occurred here in the US with the introduction of *Ae. albopictus*, as was feared. *Ae. albopictus* is an important La Crosse virus vector, as well.

The need for expanded treatment of storm water systems, documented nationwide (see Metzger et al., 2002), was proven through the surveys of such systems discussed in Section 6, above. Storm water system managers are well aware of the need to conduct maintenance on the systems (Brzozowski, 2004), which commonly includes regular cleaning of the catch basins and regarding or recharge basins. However, as is often the case, maintenance is often deferred due to short-term budgetary concerns despite calculations showing later actions result in higher costs (Reese and Presler, 2005).

Benefits from the augmented source control program of the Long-Term Plan are likely to exceed those associated with the current program. There is a discernable cost, especially associated with the expansion of the catch basin program. This will require additional staff to conduct the same kind of work. However, by increasing geographical coverage of the catch basin program, the areas where *Culex* mosquitoes are controlled may be expanded. Illness from WNV has been experienced in areas of Suffolk County where only *Culex* are present in large numbers; this suggests local sources for the mosquitoes, and, in some of these areas, the current criteria for catch basin treatments are not met. Although there is no proof that catch basin breeding results in more disease, Los Angeles (for one) found an extraordinary correlation between elimination of *Culex* breeding in storm water systems, and reductions in local cases of WNV (Kluh et al., 2005) (but Los Angeles also appears to have different *Culex* species acting as vectors for the disease). Benefits from this proposed plan of action include potential reductions in mosquito-borne disease impacts, such as reducing the potential for La Crosse virus to become established locally, and particularly reducing risks associated with WNV. Improved catch basin and recharge basin maintenance by the responsible parties could result in less use of larvicides in those environments. Potentially, improved source reduction could also limit the need for adulticide applications to control WNV risks. Potential impacts include the wastes that may need disposal due to increased stormwater system maintenance. These sediments are growing more difficult to properly dispose, as the realization that they may be enriched in hydrocarbons and metals is limiting beneficial reuse possibilities, and landfills are now few in number in Suffolk County. Collected tires, too, are a growing waste management problem, as disposal in New York is not allowed (they must be recycled, and are not supposed to be incinerated or landfilled).

7.6. Impacts of the Long-Term Plan: Part 4, Water Management

This section discusses the impacts of conducting water management. The discussion concentrates on the impacts of the 15 BMPs and 4 Interim Actions-On-going Maintenance Activities identified in the Long-Term Plan (Wetlands Management Plan section).

7.6.1. Introduction

Mosquitoes have a life cycle with two distinct parts. They spend their adult lives as air-borne winged insects. As larvae, they live in aquatic settings (Clements, 1992). Shallow, temporary, still water is favored habitat for many species for several reasons. One is that larval mosquitoes do not have gills, and so need to breathe air. Shallow environments provide access to the surface for oxygen needs and to the bottom for cover and foraging. Temporary waters reduce the number of predators, which allows mosquitoes to avoid diverting resources towards defense mechanisms. Still waters allow for connection of siphons to through the surface film to access the atmosphere for breathing.

Wetlands, once scorned and unvalued, have become prized regions in the 21st Century. This is due to their ecological and human resource values. Most derive from their geographical position at the interface between land and water (Teal and Teal, 1969). Persistent water solves many biological problems associated with life on land, and inputs of land-derived chemicals into water addresses issues caused by dilution and flow. The interface physically serves as a barrier for erosive and flooding impacts of water to land, and also serves as a means of dispersing many effects that the land can cause to areas of water.

Mosquitoes have caused and still cause sickness and misery for people. It was recognized around 1900 that mosquitoes were the vector for important human diseases such as yellow fever and malaria (Spielman and D'Antonio, 2001). It was also known that mosquitoes are relatively concentrated as larvae, and much more dispersed as adults. These facts, together with the relatively low value placed on wetlands, gave license for mass alterations of these habitats in the name of mosquito control in the early 20th Century. Wetlands were filled, drained, and ditched to reduce mosquito populations by eliminating habitat that could support larvae, and also to create land areas that had greater perceived value (Richards, 1938).

Mosquitoes still can impact the lives of most people living in Suffolk County, by threatening health and well-being. The risk of suffering these impacts is, on the whole, less in the first decade of the 21st Century than 100 years earlier, as arboviruses, while still sometimes deadly, kill fewer people than formerly died from mosquito-borne disease (Gubler, 2001), and pestiferous biting populations have been reduced (Campbell et al., 2005). Nonetheless, mosquito control principles still recognize that it is easier and more efficient to control mosquitoes as larvae. A major change is the recognition of the value of wetlands, and so modern, progressive water management intends to enhance ecological values of the wetlands being manipulated instead of ignoring these values (Wolfe, 1996).

SCVC currently is responsible for mosquito control in three distinct environments. It has responsibilities for a variety of non-mosquito control structures and conditions, such as culverts, dikes, and dredge spoil disposal areas. SCVC has responsibilities for these areas because it is the major wetlands management agency in County government. SCVC is responsible for addressing flooding, drainage, and habitat issues associated with these areas, and to ensure that these areas do not constitute major mosquito breeding problems.

The second environment where SCVC has responsibilities is the marshes where grid ditching occurred. This legacy from past practices covers over 95 percent of all the coastal marshes in the County – a review of aerial photographs found only 32 distinct areas (mostly small, isolated marshes or marsh fragments) with no ditches (see Figure 5-1). The grid ditched areas often need continuing management to:

1) reduce mosquito impacts to people; and
2) ensure the marshes are healthy, productive, and retain desired functionalities.

These responsibilities are often carried out on property owned and managed by entities other than the County, and under regimens of regulations established not necessarily to properly manage the marshes, but rather to protect them from damage.

Finally, there are marshes where SCVC does not act. Sometimes this is by self-imposed choice, and sometimes this is by fiat. Some of the restrictions are not complete restrictions on all actions, but only to a subset of the activities undertaken by SCVC, such as prohibitions on maintaining the grid ditch network at a particular marsh.

As part of the Long-Term Plan, Suffolk County has established a mechanism by which an overarching management program will be established for the County. Through the Steering Committee for the Wetlands Management Plan implementation, the County will develop a management plan that ensures the natural resources, functions, and values of the County's marshes are preserved, and enhanced where such improvements are required. As part of this effort, management of County marshes for the purposes of mosquito management will be closely reviewed, and projects will only be implemented where natural resource values will not be degraded. The Wetlands Management Plan was crafted so as to ensure these results ensue from management activities under the Long-Term Plan.

Modern mosquito management is guided by the principles of IPM. The tenets of IPM call for actions to be consonant with the threat, and appropriate for the degree of control desired. In most instances, IPM finds that control of a problem nearest to the beginning of the problem is the most effective means of control. This is generally called source reduction, and implies that addressing the source of the problem may limit impacts both spatially and temporally. Source reduction proceeds in two ways. One is control of limited problems with immediate causes, such as assisting a homeowner to eliminate standing water in the vicinity of a house. The second is water management to eliminate larval habitat (Rose, 2001).

Effective mosquito control pesticides can kill mosquitoes both as larvae and as adults (Campbell et al., 2005; Mount, 1998). The immediate aim of water management, by eliminating larval habitat, is to reduce applications of pesticides. This is a benefit for several reasons:

- The effectiveness of larvicides and adulticides is not total. Some mosquitoes generally survive treatments. Impacts to health and well-being may thus continue to occur.

- Environmental conditions, particularly weather, may make it impossible to conduct treatments optimally, or even at all.
- Mosquitoes can develop resistance to chemicals if the use of the pesticides is not carefully managed.
- Pesticides may have non-target impacts in the ecosystem. Certain pesticides may impact human health.
- Unintended accidents may result with pesticides use, resulting in human health or environmental impacts (even if such impacts are not expected to occur when the pesticide is properly applied).
- County law identifies the phase-out of pesticide use as a benefit to the County as a whole.

Effective water management can avoid many of these impacts. Water management relies on two different techniques to reduce larvae. One is to physically reduce breeding habitat. The second is to employ biological controls on larvae – predominantly, having marsh fish feed on the larvae before they can develop. The latter, if proper fish habitat can be maintained, appears to be more effective as a long-term control measure than the first (Dale and Hulsman, 1990).

Two general approaches to water management are customary in the northeast US. One is called standard water management. This is the installation of ditches, and subsequent maintenance of the ditch network. At this time, there is little need or desire to continue installing grid ditch networks, and so standard water management is the maintenance of the grid ditch legacy (Ferrigno and Jobbins, 1968). Potential environmental impacts associated with grid ditch maintenance will be discussed extensively.

The second approach to water management is more progressive and nuanced than standard water management. This is a suite of techniques developed to address perceived impacts of grid ditching, and also to more effectively control mosquito populations. This class of actions has been grouped as Open Marsh Water Management (OMWM), which consists of actions that enhance marsh conditions for fish that consume mosquito larvae in salt marshes. Creation of better fish habitat in a grid ditched marsh involves choices as to whether to keep the system open to full tidal effects or to close the system to retain water on the marsh. Many designs try to have elements of both open and closed (ditch plug) systems. Inherently, many have determined that enhancing the marsh for killifish also generally improves the marsh overall, and so, for many evaluators, OMWM is an environmental restoration technique that provides benefits, and does not have impacts (Wolfe, 1996). However, it needs to be understood that any manipulation of a complex ecological system has the potential to cause change in that system – and sometimes change for the worse. The potential for impacts from OMWM activities will also be discussed below.

In addition, the County also has the choice of not altering a marsh, and allowing natural processes to proceed in that environment. For many, this is considered to be the course of least impacts. Non-intervention in natural systems is often judged to potentially provide the most environmental benefits to the affected system. However, since Suffolk County's marshes are already managed systems, and since natural marsh systems produce mosquitoes, it is not always the choice of least impacts. Still, reversion is to be considered the presumptive interim action for County marshes, until long-term restoration management plans can be devised for each one, or unless conditions dictate otherwise. Situations and conditions where it will be best for the County to allow for marsh reversion (this process of allowing natural processes to occur) as permanent and interim measures will also be discussed.

Generally, water management, as a mosquito management tool, tends to have less potential environmental impacts than other elements of mosquito control, and if carried out in a thoughtful, progressive manner, provides environmental enhancements. For example, this appears to be the case at the Wertheim National Wildlife Refuge OMWM Demonstration Project site. Mosquito breeding was reduced and natural resource values clearly improved, at least for this the first summer following major marsh changes employing some of the BMPs discussed below (see Section 6, above, for a description of the project). The issue of concern in water management is selecting a marsh management technique that carries the least environmental risk compared to the potential environmental benefit, while also meeting mosquito control aims (Dale and Hulsman, 1990).

These comparisons will be strictly qualitative. Rigorous analysis of the various techniques under discussion is rare. This is true even for grid ditching, which has been a mosquito management technique for over 100 years. Many studies have been confounded by site specifics or short study periods that do not account for all environmental variability (Nixon, 1980). This results in conflicting results in different places, or at different times at the same settings. Some have also found that biases from natural resource or mosquito control backgrounds result in flawed perceptions. In addition, many of the discussions presented here will be predictive, rather than descriptive.

However, the generic analysis of the modification techniques, partially based on the discussion of OMWM as conducted in other jurisdictions (Section 5) will be carefully grounded in selected environments within Suffolk County (also discussed in Section 5). The scientific literature has been judged based on the overall weight of evidence, with credence given to most studies, and conflicts ascribed mostly to differences of conditions. This means that most impacts are site specific. Efforts will be made to draw broader conclusions to support generic findings, but one of the primary determinations of this analysis is that all marsh management efforts need to be carefully considered to ensure that particularities associated with each setting are properly evaluated, to ensure appropriate choices are made to optimize benefits and minimize impacts.

Although there are concerns regarding the impacts of various factors on Long Island marshes (McLetchie and Goodbred, unpublished), it is not clear that marshes on Long Island are in fact generally deteriorating. The analysis of impacts from water management will therefore not include potential effects outside those associated with conducting water management.

As discussed earlier in Section 5, Cashin Associates (CA) has determined that there are approximately 17,000 acres of vegetated tidal wetlands in Suffolk County by using a GIS interpretation of the National Wetlands Inventory. NYSDEC mapping of regulated fresh water wetlands adds to 18,084 acres. The analysis will focus on 22 different marshes in the County, as specific examples from which the generic analysis will be drawn. The 22 marshes consist of 21 Primary Study Areas (PSAs), plus the OMWM demonstration sites at Wertheim National Wildlife Refuge. These were described in Section 5, above.

As discussed in the Wetlands Management Plan (see Section 2, above, and Appendix B), 15 Best Management Practices (BMPs) and four Interim Management/Ongoing Maintenance Activities (IMAs) were identified as the most promising means of managing the County's wetlands. The potential impacts of these actions will be discussed by determining the potential impacts if they were to be applied at one or more of the PSAs and Wertheim areas. Each activity is, in a sense, an alternative to the others. The potential for negative impacts will be discussed by showing the potential affects if the BMP or IMA were to be applied at an inappropriate location. Because it is clear that selections of management alternatives must be in site-specific ways that are dependent on resource evaluations that have not yet been conducted, it will not be possible to conduct an overall evaluation of the proposed Wetlands Management Plan, per se. However, the potential impacts from the Wetlands Management Plan, both positive and negative, will be suggested, based on the site-specific evaluations.

7.6.2. Long-Term Plan (Wetlands Management Plan) Impact Assessment

The BMP manual (see Appendix C) of the Wetlands Management Plan identified 15 BMPs and four IMAs for consideration by Suffolk County in taking action in its marshes. These were categorized four ways:

1) No to little impact actions (BMPs 1-3)
2) Minimal impact actions (BMPs 4-9)
3) Major impact actions (BMPs 10-15)
4) Interim actions (IMAs 1-4)

The BMPs are arrayed in a hierarchy where actions with higher numbers may have the potential for greater impacts than those that come before. However, it may also be the case that the BMPs with greater potential impacts also offer more potential natural resource improvement. Thus, each action will be discussed in terms of potential benefits and potential impacts. Most marsh managers believe that these kinds of progressive marsh management tools offer the potential to improve marshes from current conditions. This is because most marshes, especially in Suffolk County, have been manipulated and/or managed to some degree or another already. Often the earlier manipulation or management was not implemented to conserve or improve the marsh, and sometimes the absence of essential information or the state of project-contemporary science meant that actions were taken which, in retrospect, were suboptimal. Although current progressive water management techniques are not yet truly perfected, they are better than what was once done. This means that these projects generally provide some degree of restoration or mitigation. If applied in the proper setting with skill and care, it is believed the BMPs will result in improvements to the ecology of the marsh being manipulated. The key element is to determine what kinds of settings are appropriate for a particular improvement.

There is always a degree of risk in changing complex systems such as marshes. Not all key parameters can be completely (or sometimes, even adequately) evaluated prior to taking action. The complexity of the system means that the reaction to particular actions does not need to be linear, and sometimes the results of actions are completely unpredictable, because of complex feedback mechanisms, synergies, or unexpected decouplings of system features. The most conservative approach, when dealing with such systems, is to do the least amount of manipulation to achieve the desired goal. This is the genesis of the presumptive interim policy for non-intervention in the marshes (i.e., marsh reversion). The BMPs are ordered, in essence, to accord with this conservative principle. However, it may also be that the potential for gains from more aggressive actions outweighs the risks. It may also be that the conservative approach does not address key concerns that require restoration. Therefore, in many settings, actions other than an appropriate and least impactful BMP may be selected for implementation.

Each of the 15 BMPs (and, to a much lesser extent, the four IMAs) serve as alternatives to each other. Therefore, only three explicit alternatives will be addressed in this review. Two related to continuing ditch maintenance as the sole form of water management for County wetlands. The third is to assume that no water management will be conducted. Please note for these options, maintenance of storm water related structures such as culverts, pipes, and weirs will be conducted.

Class I: No to Minimal Impact Actions

BMP 1. Natural Processes (No action/reversion)

Ditches were installed across Suffolk County's marshes in the 1920s and 1930s (Cowan et al., 1986; Glasgow, 1938). Potential impacts associated with the construction and continued presence of the grid ditch system have been reviewed above in Section 5.

Allowing natural processes to control the future of the marsh, so that the ditches will infill and so disappear (often referred to as marsh reversion), is intended to restore pre-ditching hydrology and vegetation. This is also seen as a no action management course, because it proceeds by passively allowing the marsh to return to its natural state. Philosophically, many believe that non-intervention in natural systems allows for the greatest amount of environmental benefits to accrue. This is an important element in how NPS manages its properties, for example. In a sense, reversion is the absence of active water management. Although this is a passive action, it has the potential to cause great changes to the existing status of the marsh.

Reversion is intended to minimize the effects of previous ditching activities on the marsh – both positive and negative, as not all aspects of a ditched marsh are perceived as being negative. The success of reversion as a restoration technique is dependent on the pace and kinds of natural processes at work in the particular marsh. In some settings, ditches seem to maintain themselves. Channels of a marsh in Barnstable, Massachusetts, were stable for over 100 years (Redfield, 1972). This may be generally true for ditches (Dale and Hulsman, 1990), especially if the correct length for a particular tidal regime was constructed (e.g., a maximum of a quarter-mile for Long Island's south shore) (Taylor, 1938). There are general reasons why salt marshes tend not to erode into surrounding waterbodies:

- high biomass of root materials per unit area
- large amounts of plant litter on the sediment surface
- relatively coarse particle sizes when compared to other wetland environments

(Odum, 1988)

Greater amounts of peat seem to correlate with particular marshes' resistance to erosion (Frey and Basan, 1985).

However, ditches often seem to widen in some marshes, especially at the ditch mouth, and this has been noted to occur at many Long Island marshes, according to comparisons of historical and current aerial photographs (Cashin Associates, 2006). This may be due to natural processes working to create typical marsh channel morphologies in the ditch (Pethick, 1992). The steep-sided shape of the ditches can become more bowl-like, in many instances (Miller and Egler, 1950). In some instance, ditches even erode headward, due to storm water runoff causing erosion (Mariani et al., 2003; Odum et al., 1979).

However, in many instances, parts of the ditch network infill. This can be caused by:

- siltier soils (Kuenzler and Marshall, 1973)
- shoreline drift filling the mouth of the ditch (Carlson et al., 1990)
- slumping in of the ditch sides (Lathrop et al., 2000), particularly because of rain storms at low tide (Pomeroy and Imberger, 1981)
- ice erosion (Teal, 1986)
- design flaws (primarily ditches being too long for the tidal regime, so that water flows are not sufficient to remove any accumulating sediment) (Taylor, 1938)
- plants bridging the ditch and then trapping sediments (Daiber, 1986)
- sediment collection from the marsh (Redfield, 1972)
- the general nature of the ditched marsh system (Bourn and Cottam, 1950; Miller and Egler, 1950)

Filling or collapsing ditches are cited as a reason for maintaining or reconstructing the ditches as a water management technique. Ditch maintenance is the only kind of water management explicitly allowed under New York State Tidal Wetlands regulations (6 NYCRR Part 661). For that reason, SCVC has relied on ditch maintenance as its primary means of water management.

Allowing natural processes to determine the management of the marsh may not be optimal for every marsh. The presence of ditches in almost all parts of the County's marsh system means that the environment has already been altered, and it is unclear that allowing natural processes to occur will result in remediated, good functioning salt marshes, especially on a time scale acceptable to people, in all instances. In addition, it is generally thought that most natural salt marshes will produce large numbers of mosquitoes, although the truth of this assertion is difficult to prove. Chapman (1974) asserted that "wild" salt marshes produce tremendous numbers of mosquitoes, and evidence from before the advent of large-scale ditching indicates that salt marshes on the East Coast generated so many pestiferous mosquitoes as to make their general surroundings uninhabitable (Daiber, 1986). Anecdotal information from times over the past half-century in Suffolk or Nassau Counties when ditch maintenance slacked suggests that mosquito breeding increased markedly then, too (mosquito problems may have been checked by additional pesticide use, however). The Wetlands Management Plan is based on the concept that mosquito reduction can be desirable, although not necessarily under all conditions. The general rule suggests that natural processes should be judiciously used as a long-term management selection, based on the distinctive hydrology, morphology, water chemistry, physical settings and surroundings, and substrate properties associated with each marsh. Better candidates may include those marshes where natural processes have often been allowed to be the dominant management means already, and the state of the marsh reflects robust health and a thriving ecosystem. However, in the short-term, especially when carefully monitored, reversion may be the most appropriate interim management choice. It is the choice that can most easily be "undone" (by selecting an active marsh management means). Active marsh management techniques can not necessarily be undone, if desired.

An example of a salt marsh that is a good candidate for reversion is Crab Meadow. Crab Meadow, located on the north shore in the Town of Huntington, is a parallel-ditched salt marsh with no current vector control problems. Due to the large north shore tidal range, killifish are able to access the high marsh and pond areas at Crab Meadow, limiting the amount of successful mosquito breeding. This marsh has been reverting to a more natural system for over 15 years. The upper sections of the ditches in the northern section of the marsh have been actively infilling, creating new areas of low marsh vegetation. The infilling of vegetation in these ditches is not creating new mosquito breeding habitats because no stagnant water remains in the ditches at low tide. The mouths of these ditches have widened over time and formed sparsely vegetated areas of mud that serve as habitats for ribbed mussels (*Geukensia demissa*), fiddler crabs (*Uca pugnax*), and snails (*Melampus bidentatus*) (as noted by Miller and Egler, 1950). Any alteration of the ditches would likely disrupt these special habitats. The large tidal inundation at Crab Meadow also inhibits *Phragmites australis* from invading the marsh beyond the upland fringe. Therefore, allowing the marsh to naturally revert is not likely to encourage any further expansion of this invasive species.

Another marsh where reversion is unlikely to cause any serious vector control problems is Hubbard Creek, Town of Southampton. This system is contained within a County park, one that is not being extensively used for active recreation. There are few people in its immediate vicinity. Therefore, if reversion of the ditches resulted in increased mosquito breeding, there would be little impact to any County residents. This is different from Crab Meadow, where communities nestle both the east and west sides of the marsh.

Changes in the overall hydrology of the marsh are anticipated with marsh reversion. These can result in some potential negative impacts. During the design phases of the Wertheim OMWM project, State regulators often raised the issue of drowning the marsh by retaining water on it. *Phragmites* prefers fresher conditions for seed sprouting as compared to other tidal vegetation, and ditches may enhance higher salinity conditions (Havens et al., 2003), and so allowing ditches to infill could create a fresher marsh, one more suitable for *Phragmites*. The aesthetic impact of ditches would continue for at least several years. It is also possible that the entire length of a ditch will not completely infill naturally over time.

An example of a salt marsh where reversion may result in more negative impacts is Stillman Creek. Stillman Creek is located on the South Shore in a densely populated area in the Town of Brookhaven. *Phragmites* borders the entire marsh and is encroaching upon the remaining *S. patens* and *S. alterniflora* vegetation in the interior portion of the marsh. Ditches traversing the *Phragmites* have become occluded with dead vegetation that prevents successful drainage of the marsh interior. As a result, small ponds and potholes have formed throughout the interior marsh, and serve as excellent mosquito breeding sites. Reversion at Stillman Creek will exacerbate existing degraded conditions. If occluded ditches are not able to transport saline water to the interior marsh, *Phragmites* will further hinder germination and growth of the remaining native vegetation (Havens et al., 2003). The accumulation of woody *Phragmites* stalks would then affect the detrital cycling patterns by slowing the rate of decomposition, which may raise the elevation of the marsh (Niedowski, 2000). As a consequence, waterfowl and wildlife that utilize the existing low marsh vegetation would also be impacted.

The low tidal range of the South Shore and the large berm located along the southern marsh boundary currently hinders fish access to the marsh interior. Fish access and diversity would significantly decrease as ditches infill over time, given that ditches are considered to increase fish habitat, by up to a factor of five (Kuenzler and Marshall, 1973). On marshes with low tidal amplitude such as Stillman Creek, poor tidal exchange with the estuary tends to result in the stagnation of water in ditches. This often results in generally poor water quality, making the ditches difficult habitat even for killifish, and this can lead to increased successful mosquito breeding.

Factors that support successful use of natural processes as a management tool include:

- historical marsh health in the absence of ditch maintenance
- large tidal exchange rates, fostered by some combination of a large tidal range, a good estuarine connection, few barriers to internal water flows, and/or an extensive natural creek system
- infilling ditches from upland ends (potentially eroding at the mouths)
- relatively few people to be impacted by mosquito breeding
- killifish habitats other than ditches
- patient managers willing to allow processes to occur deliberately

The absence of some of these factors suggests that natural processes may not be the optimal management tool to use at the marsh being considered.

BMP 2. Maintain/Repair Existing Culverts

Many culverts provide insufficient inundation because of their size, placement, or from blockage by debris (Niedowski, 2000). When it is determined that the existing culvert size provides adequate inundation, culvert maintenance should be performed to maintain the culvert effectiveness. Maintenance includes clearing blockages, replacing damaged pipes, and controlling erosion around the structure. The need for maintenance is determined when unexpected flooding occurs and is reported, or by inspection. Maintaining or repairing existing culverts allows tidal flow to be maintained to the marsh, while preventing undue flooding behind the obstructing structure that the culvert penetrates.

An example of a salt marsh where maintenance of the existing culvert would be beneficial is Pipes Cove. Pipes Cove is located in the Town of Southold, fringing the Peconic Bay. Pipes Cove is a healthy salt marsh that receives adequate amounts of tidal inundation to the high marsh areas during extreme high tides. There are no tidal lags or significant vegetation differences between the marsh upstream and downstream of the culvert, and flooding is not a concern to adjacent areas. Marsh vegetation north of the LIRR tracks is predominantly high marsh with low marsh fringing the ditches and tidal creek. The low marsh vegetation along the ditches and the small amount of *Phragmites* indicates that adequate amounts of saline water reach the back marsh (per Bart and Hartman, 2002). Maintenance of the existing culvert will sustain existing vegetation patterns and hydrologic conditions.

A potential impact would be the continuation of possibly polluted runoff from upland sources into the adjacent water body (Fultz, 1978; Cory and Crosthwait, 1939). The predominant land uses surrounding Pipes Cove are light residential, with one industrial establishment. The northern portion of the marsh is buffered from Pipes Neck Road and residential housing by woodlands (100 meters at the widest point). This upland buffer thins out towards the northwestern portion of the marsh to less than 10 meters wide. A welding and supply company operates adjacent to Pipes Cove Creek, north of the train tracks. Any runoff received from the welding and supply company or from the roads would continue to be transported into the waters of Pipes Cove through the existing culvert.

Since the existing culvert runs under the LIRR tracks, more significant impacts would be associated with a culvert upgrade. A section of the tracks would have to be dismantled, disrupting service for an extended amount of time, causing a burden on travelers. Coordination with the LIRR to access the culvert would also have to be arranged to include determining an appropriate location for staging area to perform routine maintenance, refueling operations, and equipment storage. Accessing the culvert with heavy machinery may cause impacts to the surrounding marsh vegetation, since the only access point would be through the marsh itself. Machinery would disturb *Phragmites*, and most likely the low marsh and high marsh vegetation near the culvert.

If a culvert that is deemed adequate is not maintained, tidal flow could become constricted by debris. Impacts resulting from restricting the tidal connection may include changes in the frequency, volume, and duration of tidal flooding. Tidal restrictions can also change marsh vegetation, morphology, subsidence, water quality and salinity and soil oxidation (Niedowski, 2000). A lack of inundation reduces or eliminates the extent of fish use of the marsh (Burdick et al., 1997). Salt-tolerant vegetation may be replaced by other species, and *Phragmites* will often invade these disturbed areas (Roman et al., 1984).

Culvert maintenance perpetuates existing conditions, and therefore should not be considered unless the marsh is viewed as healthy. Cedar Beach, located at the southeast tip of Great Hog Neck in the Town of Southold, is an example of an unhealthy marsh, possibly with an inadequately sized culvert. Cedar Beach is connected to Cedar Beach Creek via a culvert underneath Cedar Beach Road. The marsh is considered to be unhealthy because there is little exchange between the marsh and estuary, limited amounts of fish and wildlife, and a large perimeter border of *Phragmites* that is actively invading the remaining native marsh vegetation. In addition, significant vegetation differences exist between upstream and downstream sides of the culvert. The vegetation downstream of the culvert consists of mainly *Spartina* grasses, while upstream of the culvert is dominated by *Phragmites.* These conditions suggest that the existing culvert size may be inadequate. The poor tidal exchange promotes poor water quality of the ponds and pannes throughout the mid-section of the marsh. If not upgraded, it is likely that marsh vegetation, fish and wildlife habitat, and water quality would continue to degrade. A better alternative for this site, when maintenance is required, would be a culvert upgrade.

BMP 3. Maintain/Reconstruct Existing Upland/Fresh Water Ditches

Ditches were installed in fresh water wetlands generally to increase drainage and so provide a degree of mosquito control. Because they provide drainage, they often serve important roles in storm water management. These systems are found in some areas that are now extensively developed (such as Mastic-Shirley and Oakdale), in agricultural areas (especially in Riverhead and on the North Fork), and in areas that have very little development (such as Manorville). The primary reason for SCVC to maintain such ditches today would be to continue historical water management for flood control reasons. The focus of efforts will be in the areas where flooding will affect residents' use of property and local streets, although some systems are also maintained in order that existing agricultural uses can continue.

The Federal Phase II storm water management effort requires municipalities to develop plans to mitigate the direct discharge of storm water into open bodies of water. It is not clear how these ditches, generically, would be treated under Phase II planning. Where ditches contain water most of the time, and merely collect run-off, they may not be considered water bodies that are subject to the Phase II requirements (as they would be receiving waters). Where the ditches are dry most of the time, or run-off is directed into the ditches by other structures, they may need some form of treatment to meet the statute, because they may be acting as storm water systems.

A marsh that would benefit from maintaining existing upland ditches is Johns Neck Creek. Johns Neck Creek is a 76-acre salt marsh located in a densely populated area in Mastic-Shirley on the South Shore. The upland perimeter of the marsh is bordered by fresh water wetlands. Existing upland ditches minimize freshening of marshes by draining the standing fresh water off the marsh surface. The upland ditches are located within dense stands of *Phragmites* which have become occluded with *Phragmites* wrack and debris and do not drain effectively. These ditches do have a tendency to back up into the surrounding residential areas just outside of the salt marsh, through which the ditches run (serving as storm water drainage systems). Maintaining these upland ditches will re-establish drainage flow and decrease the amount of standing water where fresh water mosquitoes may breed. Certain fresh water mosquitoes are essential for EEE transmission (*Cs. melanura*); others are believed to be the main vector for WNV (*Cx. pipiens*). Although neither of these mosquitoes would breed in these areas, other flood water mosquitoes that are important bridge vectors for these diseases (such as *Ae. vexans*) can breed in these areas. *Ae. vexans* is also a very aggressive human biting mosquito, and broods can cause extreme discomfort for people of the area. By limiting the amount of standing fresh water, mosquito breeding will decrease and potential health risks to area residents will be reduced. Increasing drainage of the upland fresh water wetlands will also aid in controlling *Phragmites* (Buchsbaum et al., 1998) and reducing flooding of adjacent residential properties.

Lots in this area tend to be small. There are few undeveloped areas that have not been reserved for parks or other natural resource reasons (such as the Johns Neck Tidal Wetland). Alternative means of flood water management are not easy to develop there, especially given the high water table, which precludes underground structures of recharge basins. For this reason, conveyance of storm waters away from housing is an important consideration.

Hand tools will be used to maintain most upland ditches; however, it is more likely that heavy machinery would be required on larger marshes with extensive upland ditches that have filled in significantly over time, such as Johns Neck. Since the fresh water ditches at Johns Neck are located in the upland *Phragmites* border, *Phragmites* would be the vegetation impacted. High marsh vegetation consisting of *S. patens* and *D. spicata* may also be impacted, but this would be limited to a small section near machinery access areas. Some impacts encountered with the use of heavy machinery are:

- soil compaction;
- plant root damage; and
- rutting of the marsh surface.

A negative impact that may be associated with maintaining these ditches at Johns Neck Creek is that the upland ditches will transport runoff into the adjacent water body. It is believed that ditch systems may channel storm water and run-off into estuarine systems; storm water run-off has been shown to contain contaminants such as sediments, nutrients, petroleum hydrocarbons, pesticides, trace metals, and pathogens (NYSDEC, 1996a; Lee and Jones-Lee, 2005). Reducing retention of storm water (which allows for degradation of those elements of storm water that are subject to chemical and biological decay) and detention times (which minimizes the amount of particles and particle-reactive substances that can settle out) could lead to greater pollutant loadings to the estuary. The trade-off is between the impacts of the run-off, and the benefits of flooding reduction and increased mosquito control. In addition, some mitigation is offered by the need for the Town and County to find storm water treatments, where possible, for direct discharges into surface waters.

The ditches in the Manorville area will not be maintained. This is because it is an important natural habitat region, with unique species distributions primarily due to surface water systems.

There do not seem to be many advantages to maintaining the ditches. There are few people in the Manorville area, and so there is less infrastructure and property to protect from flood damage. Maintenance of the mosquito ditches may support the existing habitat (which, in a sense, was partially created by the ditches); however, the maintained ditches could also be effective at removing water from the habitat. The surface water habitats by and large pre-date mosquito ditching, and so it is far from certain that the ditches contribute to the important elements of the habitats found in this area. Maintaining ditches may have an impact on important surface water features, and lead to threats to some of the important rare species in this area.

EEE is propagated in Manorville from time to time; effective drainage of red maple swamps might reduce *Cs. melanura* numbers, and therefore amplification of the virus. However, it is difficult to drain red maple swamps to the degree required for effective mosquito control, especially without the construction of new ditches. Maintenance of existing ditches is not likely to drain the swamps as needed to impact *Cs. melanura* habitat. Therefore, it is unlikely that effective reductions in health risks can be achieved through water management. Indirect improvements in health risk may be achieved by targeting fresh water areas that support bridge vector species such as *Ae. vexans* and *Oc. canadensis*. Most EEE-related mosquito control in Suffolk County has been accomplished by targeting bridge vectors with adulticides. It is not clear that attempting to reduce the numbers of fresh water bridge vectors permanently can be achieved through maintenance of existing ditches. Effective reductions in bridge vector numbers are likely to require installation of more ditches (and the installation of the ditches to drain some of the key natural resource features, such as surface water bodies, discussed above). The County does not intend to construct more grid ditches in wetlands, for any reason. Installation of more ditches is unlikely to occur under the current NYSDEC regulations (6 NYCRR Part 663), in any case. In addition, some consider red maple swamps to be a unique and important ecological resource in need of preservation.

A potential benefit from the maintenance of upland mosquito ditches, not demonstrable through any of the PSAs, is the support of preferred spotted turtle habitats. These turtles were found to be in ditches in the Napeague salt marsh by various researchers. Further research supported by the Long-Term Plan (discussed in Section 6, above) found that the turtles overwinter in fresh and brackish water areas of the marsh, and that they seem to prefer the ditches to other marsh habitats (partly because natural fresh water aqueous environments are somewhat lacking in this marsh). Therefore, these ditches may be important habitats for the turtles. This also means that maintenance of the ditches needs to be carefully done. The turtles emerge from hibernation in late spring, although there are some indications that the ditch environment at Napeague may allow the turtles to be active all winter; more typical hibernating behavior suggests that winter maintenance of ditches in the upper, fresh water reaches of marshes should be subject to certain restrictions, to ensure turtles are not harmed.

Class II: Minor Impacts

BMP 4. Selective Maintenance/Reconstruction of Existing Salt Marsh Ditches (Standard Water Management)

As discussed in Section 5, there are many disputes regarding the potential for environmental impacts and benefits associated with mosquito ditches. This means that the impacts associated with maintenance of ditches are similarly affected by a lack of consensus.

Maintaining ditches reinforces all of the issues raised in Section 5, good and bad, because it perpetuates the ditched system. Modern ditch maintenance may also have a few effects of its own. Although low ground pressure equipment is used, there is always the chance of damage to the marsh from the use of heavy equipment. In addition, the casting of spoils can have impacts – from spreading *Phragmites* rhizomes to burying marsh vegetation deeply enough that it cannot recover. Thoughtful work plans avoid these impacts. Organisms using the ditches for cover may be harmed by ditch maintenance. This may have been the case for some spotted turtles in Napeague in 2000, where some study participants claim turtle losses were documented (others do not have any such records). Heavy equipment also can affect nesting, courting, and other marsh uses by birds and other organisms. Again, such impacts can be mitigated by limits on the seasons that the maintenance occurs in.

Maintenance of an existing grid-ditched system has been called "standard water management." Ditch maintenance involves:

- the cleaning of ditches;
- regrading berms to allow water to access the marsh during flood tides; or
- the removal of other obstacles to allow tidal flow onto and through the marsh to areas of mosquito breeding.

Ditch maintenance offers the opportunity to address mosquito problems through source control, with the least disturbance to the existing environment. This is the case because nearly all of the County's salt marshes were ditched between 1900 and the 1990s (with most of the work done in the 1930s). Changing complex systems as little as possible is sometimes the best alternative as, when existing systems are manipulated, it is often impossible to determine exactly how much change will result in a cascade of deleterious results.

As envisioned in the Wetlands Management Plan, standard water management is to be a designed process. Ditch maintenance will be the technique that is selected under a few, defined sets of conditions. Existing water management systems (ditches, culverts, and other structures) will normally be either left alone, if not needed for mosquito control, or upgraded to BMPs as outlined in the Plan. In some cases, implementation of BMPs is not immediately feasible due to lack of pre-project information or institutional factors such as landowner policies. Implementation of BMPs may also not be immediately feasible due to lack of resources. For instance, if major tidal flow restoration is desirable but is currently too expensive because it involves major road work, interim measures should be taken while these resources are sought if the alternative is a loss of habitat and/or an increased reliance on pesticides.

Assuming Long-Term Plan water management policies are implemented (especially these progressive water management strategies), the general presumption will be against maintenance of ditch systems. However, in limited circumstances, existing structures may be maintained on an interim basis, when the following conditions are met:

- Deterioration of or damage to structures is resulting in a significant mosquito problem, as evidenced by larval and/or adult surveillance, serious enough to require control. An example would be a collapsed pipe that restricts tidal flow and results in a need to larvicide an area. Or:
- Failure to maintain the structures would result in the loss of resource values, such as fish passage or tidal flow, or loss of vegetation due to fresh water impoundment. Or:
- Failure to maintain the structures would result in a hazard or loss of property as a result of flooding.

Benefits to be expected from the work include:

- Maintaining or reconstructing the existing structures will improve water circulation or provide fish habitat sufficient to reduce the need for pesticide application.

- Maintaining the structures is compatible with habitat values that existed prior to the failure or deterioration of the structures.
- Maintaining the structure will prevent flooding or other hazards.

Constraints on any maintenance of a pre-existing ditch system include:

- The structures will be maintained essentially in-place and in-kind.
- Disruption of wildlife habitat due to construction will be minimized by limiting work areas and/or by using seasonal constraints.
- Listed species will not be adversely impacted.
- Interim maintenance will not lead to excessive drainage that would result in a loss of wetlands values.
- The action will not lead to increased or more direct conveyance of inputs from storm drains or other structures.
- The action will not preclude the implementation of BMPs when resources and/or institutional considerations allow.

As with most water management for mosquito control, the intent of any ditch maintenance will be to enhance the local conditions to support killifish predation on mosquito larvae. This means ditch maintenance will be undertaken to increase water flows, reconnect stagnant areas of the marsh to improve circulation, or to provide refuges for fish from bird predation. It will only be undertaken in areas with excessive mosquito breeding, so that an impact will be the reduction in disease risks. It is also possible that ditches will have obstacles removed to promote drainage of standing water that is breeding or has bred mosquitoes. This can reduce the need for pesticides applications.

In a very few instances, where short stretches of clogged or littered ditches can be simply addressed, and the benefits will be immediate and the entire project is of overall limited scope, simple hand clearing of ditches will be allowed. In almost all instances, however, the causes of ditch clogging will be investigated, and steps taken to limit repeated maintenance efforts. This may require widening stretches of selected ditches, establishing baffles to prevent erosion (through installing small curvatures in the ditch pathway, for example), and other steps necessary to make the tidal hydrology work to maintain the ditches rather than to fill them.

This kind of modified standard water management, where the maintenance activities are carefully planned, and targeted to achieve maximal results, is best suited for wetlands where existing conditions meet the landowner's long-term expectations, but where mosquito problems have occurred. An example where ditching could be selected as an appropriate long-term treatment is the Pickman-Remmer salt marsh, located in a densely populated area in the Town of Oakdale. The vegetation in the western segment of the marsh is dominated by *S. patens.* The terrain is hummocky and serves as mosquito breeding habitat. The existing ditches drain the marsh into the adjacent canal, preventing flooding of upland residential properties. Some of the ditches in the western segment of Pickman-Remmer are occluded with marsh vegetation and prevent water flow. This condition makes the ditches become stagnant which may create new mosquito breeding areas, hinder fish access, and decrease habitat values. Standard water management implemented in these clogged ditches would make this fish habitat more viable. Ditches could be cleaned of the plant material, with some deeper refugias installed closer to peak breeding sites. The sediments generated by this work should be sidecast into the hummocky high marsh areas, to further minimize mosquito breeding (see BMP 8, below).

Heavy machinery would be required since sidecasting would be involved. The machinery would travel over *S. alterniflora* along the ditches and over *S. patens* and *D. spicata* when crossing the marsh. Low ground-pressure machinery should minimize damage to the vegetation, but careful monitoring would be required to ensure there is no damage to root structures. Ruts are always a concern, even with low ground pressure equipment, and could result in standing water that creates new mosquito breeding habitats. Also, machinery constantly traversing the same area could damage existing vegetation.

Maintenance of the ditches is likely to improve water quality enough to promote good fish habitat, which will help enhance mosquito control, without causing a major disturbance in the marsh. This may be important, because impacts from surrounding development on the Pickman-Remmer marsh are more likely than in some other cases. This suggests it is an area where fewer alterations may be better than making major changes, as the cumulative effects of those from development with added stressors such as marsh manipulation are difficult to forecast. Therefore, the effect of a major marsh restoration attempt here, with all of the factors that may come into play, is less predictable than the effects from a similar project in a less complicated setting.

Pickman-Remmer might be a good candidate for modeling of water flows. Ditch maintenance has been undertaken in this marsh before, and so the existing water flows are not sufficient or well-directed enough to avoid ongoing ditch clogging. The wetting-drying model for the South Shore Estuary might be extended up into this marsh, although a careful survey of existing conditions would be required. The model could forecast changes to tidal water flows that could be generated by selective widening, deepening, or even narrowing of selected ditches within the marsh (R. Wilson, Marine Sciences Research Center, Stony Brook University, personal communication, 2005). Such analysis could support the use of ditches as an effective means of treating the mosquito problems found in the marsh.

Ditch maintenance will not address all issues that are found at Pickman-Remmer. In particular, the segment of the marsh east of the Grand Canal is severely degraded. *Phragmites* dominates this segment with only a few patches of *S. patens.* Tidal flow is restricted by a large berm that runs the length of the marsh. Three culverts breach the berm to allow drainage of the marsh into the canal. Salinity and dissolved oxygen measurements in the eastern segment of Pickman-Remmer were considerably lower when compared to the western segment. These measurements and the existing vegetation differences are evidence that the eastern segment receives less tidal exchange. A more aggressive approach than ditch maintenance would be needed to restore this segment of the marsh.

Ditch maintenance is the most conservative means of large-scale water management, and will perpetuate existing conditions. Ditch maintenance is not appropriate for salt marshes with a history of continuing maintenance needs, and where aerial larviciding has been required despite maintenance of the ditches in past years. An example of such a marsh is Namkee Creek, located on the South Shore in the Town of Islip. Namkee Creek has been extensively grid ditched and receives aerial larvicide applications. The ditches at Namkee Creek are not functioning effectively in terms of eliminating mosquito breeding habitats. The existing grid system does not reach all of the ponds and pannes throughout the marsh where mosquitoes may be breeding. More aggressive water management needs to be considered for this marsh in order to effectively limit mosquito breeding.

BMP 5. Upgrade or Install Culverts, Weirs, or Bridges

BMP 2 discussed replacing culverts and similar structures with in-kind structures. In some cases, it is necessary to improve the water management device that is currently in place. Areas where the estuary has lost its connection with the salt marsh ("formerly connected" marshes, in the categorization of NYSDEC) constitute some of the most seriously impaired salt marshes in the northeast US. They are frequently identified as remedial candidates (Fell et al., 2000).

The purpose of upgrading or installing culverts, weirs, or bridges is to increase tidal flow onto the marsh. Tidal restriction is widely recognized as the greatest problem for remaining Long Island salt marshes, and has been a driver of remedial designs. SCVC involvement in this work stems from its responsibilities for "legacy" installations, and the knowledge that better water quality in wetlands invariably means more fish, which tends to disrupt mosquito breeding.

The need for augmenting flow through such structures can be signaled by problems involving:

- tidal lags
- flooding history
- constrictions (indicated by excessive flow velocities in the pipe)
- vegetation differences between marshes upstream and downstream of the structure
- differences in key water quality parameters between the upstream and downstream marshes

The presence of these problems signals that replacement with in-kind structures will perpetuate the problem, which is necessarily sub-optimal management.

Tidal lags are the result of constrictions in flow, so that the tide does not propagate through the water management structure properly. A tidal lag is signaled by a delayed high or low tide on the upstream side of the culvert, or by diminishment of the amplitude of the high tide. This is a result of the piping being unable to convey a large enough volume of water on demand. This could be due to an inadequate diameter, or excessive frictional losses. Frictional losses mean that remediation of the problem may need to consider more than the apparent cross-sectional area needs to solve the problem; therefore installing several small pipes may not be as efficient as installing one larger pipe.

Flooding history (water backing up on the upstream side) is also a sign that the culvert is inadequate for its intended purpose. Flooding problems are not as easily observed as tidal lags, as they clearly require an irregular event to spawn them. It may be appropriate to calculate flood conveyance requirements whenever any of these structures requires maintenance, to determine if flooding can be anticipated and forestalled.

A constriction is the minimalist sign that the culvert is not the right size. The high velocities signal that the pipe is conveying the water, but with stress. The high velocities can impede access by aquatic species, or cause damage to those animals that attempt to traverse the passage. In addition, high velocities could increase the potential of erosion issues.

Vegetation differences from one side of a culvert to another may indicate the culvert has affected the local ecology. It may also indicate that conditions on one side of the culvert are different from those on the other for reasons that have nothing at all to do with the culvert (the culvert may be for a road that was installed where the salt marsh became fresh, for example). Many of these instances rely on common sense for resolution: high marsh downstream, *Phragmites* upstream, for example. The same holds true for significant changes in water quality parameters. It may be that the culvert was installed where a stream met the salt water; or it may be that well-mixed, clear, high oxygen content water lies downstream of the culvert, and stagnant, eutrophied, low dissolved oxygen water lies upstream of the culvert. Visible differences such as those are indicators of a lack of exchange across the culvert.

Cedar Beach is an example of a salt marsh that would benefit from a culvert upgrade. Although flooding is not an issue at Cedar Beach, there is poor exchange between the marsh and the estuary. The best sign of this is vegetation upstream differs from vegetation downstream. Vegetation south of Cedar Beach road consists mainly of *S. patens* and *S. alterniflora*, with little evidence of *Phragmites*. North of the culvert, the vegetation changes to predominantly *Phragmites* with only a small section of high and low marsh grasses in the interior section of the marsh. Upgrading the existing culvert size would increase tidal exchange and inundation to the marsh north of Cedar Beach Road. This will result in mosquito control benefits, as it should improve water quality by enhancing tidal circulation, therefore increasing habitat for killifish on the upstream side and improving fish access to breeding areas. The enhanced tidal circulation may also reduce mosquitoes by impeding the conditioning process of the eggs and decrease the amount of standing water available for mosquito development (see Kramer et al., 1995). In addition, increasing tidal flow can increase salinity. Higher salinities are often identified as a means of reducing invasive *Phragmites* extent (Bart and Hartman, 2002).

Whenever the hydrology of a marsh is substantially altered, potential negative impacts may result. Increasing the culvert size may increase the amount of standing water on the marsh surface by promoting greater amounts of flooding on each tide. The marsh surface usually comes into dynamic equilibrium with the tidal regime, with sediment accumulating at the approximate rate of sea level rise (for mature marshes that is). This process may take decades to come back into balance when the hydrology is changed a great deal, or may require vegetation shifts. Until the equilibrium is reestablished, water may be in excess on the marsh, creating new mosquito breeding habitats. The new water conveyance capacity may allow for storm tides to flood upland areas that formerly were protected. An opposite problem can also occur: the marsh had been supported by the excessive water retained behind the water management structure. With a "properly" sized structure, the marsh may be subjected to excessive drainage. This may also hold for the adjacent uplands. Changes in the overall hydrology of the site will probably be reflected in the site, and so may result in some large ecological impacts, again, reinforcing the necessity to evaluate each site prior to undertaking such actions.

Heavy machinery would be required for upgrading the culvert at Cedar Beach. Given that the culvert runs under Cedar Beach Road, the scope of the project increases significantly. In addition to the monitoring of impacts associated with the use of heavy equipment on the marsh, coordination with the Town of Southold Highway Department would be necessary. Associated impacts would include major road construction, and an inconvenience to the surrounding residents that use the road.

Upgrading a culvert size may not be suitable for every marsh that has a culvert that separates two parts of the marsh. The marsh at Pipes Cove is divided laterally by Long Island Rail Road train tracks. A culvert under the tracks connects Pipes Cove Creek to the northern marsh. Marsh vegetation upstream and downstream of the culvert is similar, consisting mainly of *S. patens, D. spicata*, and *S. alterniflora*. Although the expanse of *S. alterniflora* along the ditch edges on the downstream side of the culvert is much larger, the similar vegetation patterns suggest that the culvert size is adequate and tidal exchange upstream is sufficient. Enlarging this culvert would alter the tidal regime and affect the current vegetative communities present in the marsh. This could result in the expansion of *S. alterniflora* along the ditches similar to the extent of existing *S. alterniflora* along the ditches downstream of the culvert. Conversely, a larger culvert could result in the excessive drainage of water formerly impounded up on the marsh, causing changes in vegetation to species that prefer drier marsh conditions. Salt-tolerant vegetation could be replaced by other species in areas that are no longer inundated.

An increased amount of inundation may also flood adjacent areas. If the marsh upstream of the culvert receives the same amount of inundation as downstream, it is possible that northwest portion of the marsh would flood onto Pine Neck Road during extreme high tides.

BMP 6. Naturalize Existing Ditches

Maintained mosquito ditches have several features that tend not to be found in natural water courses. These include:

- straight (steep) sides
- linear courses
- even widths

Many mosquito ditches often have berms. This feature is sometimes found along streams and rivers. There are three explanations for the berms along mosquito ditches:

- spoils were sometimes placed right along the bank of the ditch (Miller and Egler, 1950)
- *Phragmites* may have colonized the drier soils along the bank (Bart and Hartman, 2000); *Phragmites* tends to accumulate sediments in its root structure, raising the plant above its surroundings (Meyerson et al., 2000).

- higher velocity water contained with banks, when it overflows those banks, tends to slow (the same or slightly larger volume of water now covers a much larger area), causing it to lose its ability to transport sediment. This results in sediment accumulations bankside (Wiegert and Freeman, 1990).

The last condition may not hold true for all tidal settings. In general, tides are not contained within the banks of the ditches or natural streams, but encompass such a large volume of water so as to make the enlarged area somewhat inconsequential. This is not true for all tides, and all marsh settings. Nonetheless, tide overflows may not be a compelling explanation for berms at mosquito ditches.

In any case, the four conditions associated with ditches can be addressed to remove some of the unnaturalness of the ditches. There are often benefits other than aesthetics that can be achieved.

Naturalizing existing ditches generally consists of incising meanders to create sinuosity across the straight-line existing plan. These meanders will break through the berms, establish a less linear environment, and may change the hydrology of the existing ditches. The naturalization of ditches will generally have small effects on mosquito breeding, and so is a technique best used to augment other means of controlling breeding.

Berms can sometimes hold water behind them. This defeats the intent of the ditch – to drain water off the marsh (Shisler, 1973). A meandering water course expresses tidal energy better. Straight line, uniform size ditches lose too much energy to friction, whereas more natural forms allow for tidal energy to be transmitted far into the marsh (Pethick, 1992). A more natural design may lead to natural maintenance of the waterway. Creek bends and other places where flows slow also allow for wrack to accumulate, which can cause breaks in the vegetative monocultures that are sometimes found along ditches (Fischer et al., 2000), which may or may not be perceived as a benefit.

Natural tidal channels tend to have steep sides, due to peat retaining its cohesiveness even in the face of erosive forces. Gentler sides to the waterway can entice fish to leave it, and venture out onto the marsh (McIvor and Odum, 1988). This has the potential to increase the area where mosquito consumption occurs and so may have mosquito control benefits.

The prime benefit is the aesthetic improvement. Reducing the linear appearance of standard grid ditching is generally well received.

As a component of a larger project to enhance mosquito control efforts, selective ditches at Wertheim National Wildlife Refuge were naturalized. Area 1, the first portion of the salt marsh altered at Wertheim, is approximately 40 acres in size, actively breeds mosquitoes, and was being invaded by *Phragmites*. Linear ditches ran perpendicular to Carmans River. Most of these ditches were filled as part of the project. Some of the ditches that remained open to the river were altered to be more sinuous. This mimics naturally occurring waterways, although the curvature of the naturalized streams is less than is often found in natural settings. In one instance, a ditch in the northern section of the marsh was curved into an area, one dominated by *Phragmites* and riddled with small potholes. The diversion into this area was designed for several reasons. One was to increase salinity levels in a *Phragmites* area. Secondly, the ditch serves as habitat for mosquito consuming fish, and increases access for these fish to the pothole area, which supports mosquito breeding. The ditch now traverses more habitat types than it formerly did, which may increase the diversity of life using the waterway. More natural flows may increase reactions between the substrate and the water, and increase the filtration processes associated with the wetland. Thus, effects of naturalizing a ditch include improved habitat and access for fish, while the greater sinuosity may also lead to more diverse micro-habitats, and create small areas of cover, which can lead to greater wildlife use of the channel.

Naturalizing ditches, however, will likely change the hydrology of the ditch. Meandering streams often have erosive patterns where the outside bank has deposition and the inside bank erodes (because of the velocity differential in the path lengths). The peat of the marsh is likely to be generally resistant to these impacts – as is demonstrated by the persistence of natural marsh channels and many ditches. Meanders will increase streambed length, which should lower overall velocities of the tidal prism. This may encourage infilling, or may result in more natural dissipation of tidal energies. After one year at Wertheim, nearly all of the altered, naturalized ditches have maintained their constructed shape. There is one area of localized bank erosion, where it appears that both rising and falling tides moving through the ditch focus energy on one stretch of bank. This area is being monitored to determine if remedial actions need to be considered.

Naturalizing ditches, in and of itself, is not necessarily the best allocation of restoration resources. It is effort intensive, but, except for the aesthetic impacts, the results of the work tend not to be as great as some other more direct efforts. Mosquito control benefits are slight, and the habitat enhancements are likely to be realized only as adjuncts to other more substantial efforts. Naturalizing ditches has the potential to result in erosive, unstable waterways. These are exactly the environments where intense mosquito breeding has been documented (see Collins et al., 1986). In addition, the construction of meanders entails the loss of some vegetation (perhaps offset by the filling of the linear portion of the ditch). If it is true that drainage associated with ditches is limited to the immediate vicinity of the ditches (Rockel, 1969), then extending the path length and penetration of the panel by such structures may result in drainage greater than that associated with the original ditches.

Heavy machinery would be required for the creation of a new tidal channel. Damage to root structures may occur even with low ground pressure equipment, if too many trips over the same area occur or if the equipment is used during times when the marsh is excessively wet.

BMP. 7 Shallow Spur Ditches

Fish access to breeding areas is key to effective, long-term, consistent control of mosquito breeding. Even with the extensive use of ditches across the County's marshes, many areas remain 50 feet or more from any water. This lack of easy access to much of the marsh where breeding may be occurring can be addressed in many different ways. One of the least intrusive is to install spur ditches from a permanent body of water to a consistent breeding site. At higher tides, the shallow ditch contains enough water for killifish to easily navigate. At lower tides, it empties, and so breaks the hydraulic connection. This prevents complete drainage of the upgradient portion of the ditched area.

Spur (sill) ditches can also be installed to provide a hydraulic connection between a pond and a channel or ditch. This increases water circulation into the pond, which can be important, especially in low tidal regimes where water exchange under natural conditions to isolated ponds will not be vigorous enough to maintain good water quality. Use of a shallow connection prevents over draining the pond at lower tides.

Spur ditches may be perceived as mini-ditches. Many are linear, and often have unnatural morphologies, such as leading to dead-ends, or being of unusual depths (shallow features for moving water are rare on a marsh). Spur ditches are an effective means of extending the impact of water management structures into the heart of mosquito breeding areas, however.

There are some questions regarding the ability to construct spur ditches to meet design needs in all cases. At the Wertheim OMWM, some spur ditches connecting large ponds to ditches appeared to be eroding deeper into the marsh peat, due to the head of water associated with the lag created between the height of water in the pond at low tide, and the height of water in the ditch. Although the maximum difference in water levels between high tide and low tide was on the order of one foot to 18 inches, the sill ditch appeared to be eroding from an initial depth of approximately six inches to nine or more inches deep. This process appears to have stabilized, although the spur ditch increased in depth to approximately one foot. Spur ditches at the same hydrological level, such as those extending from a pond to a breeding location, would not have this apparent problem.

An example of a marsh that would benefit from the construction of shallow spur ditches is Cedar Beach. The ditches at Cedar Beach are spaced approximately 60 meters apart and run perpendicular to the tidal creek. Areas between these ditches are riddled with numerous shallow ponds and pannes. Due to the lack of tidal inundation of this marsh, few fish are able to access the ponds and pannes between the ditches. The construction of spur ditches off the main ditches to these areas would increase the circulation between the larger waterways and these isolated bodies of water. It is likely that the water quality of the ponds and pannes connected to the spur ditches would improve, and fish habitat would be enhanced.

The numbers of mosquitoes that survive to pupate as adults on the marsh surface are negatively correlated with both tidal inundation and the number of mosquito consuming fish (Buchsbaum, 2001). Therefore, increased inundation through the construction of spurs would allow fish access to the marsh surface to feed on mosquito larvae.

A potential negative outcome of constructing spur ditches is the possible excess drainage of the ponds and pannes. Spur ditches will slightly alter the hydrology of the marsh and as a result, marsh vegetation may change. If the amount of inundation increases in high marsh areas at Cedar

Beach, existing *S. patens* and *D. spicata* vegetation could be converted to low marsh vegetation over time. Spurs are a form of ditching; as such, they have many of the negative connotations associated with full ditching. Spur ditch aesthetics is not a robust field, and efforts need to be undertaken so that design needs are addressed without inscribing more straight lines on a marsh.

Spur ditches have the promise of addressing localized areas of breeding without major impacts to the existing marsh setting. Spur ditches may serve as fine touch-up tools following evaluation of a large water management project. Then small areas of mosquito breeding could be quickly and easily addressed by adding spur ditches, rather than re-engineering the entire project to address a few missed or unsuccessful breeding location removals.

Heavy machinery is required when constructing spur ditches. Placement of the excavated material should be carefully considered. If sidecast, it is possible that clumps of excavated material (such as *S. patens*) could get washed into the spur during high tide, causing occlusions.

BMP 8. Back-blading and/or Sidecasting Material into Depressions

Spartina patens tend to grow in groups of plants, where they form raised areas above the general elevation of the marsh. This creates small potholes and makes the marsh terrain hummocky (Nixon, 1982). These small potholes serve as very effective mosquito habitat, because the area where *S. patens* thrives is not regularly flooded, but rather only is covered by the tides on the higher monthly tides. Elimination of the potholed areas provides a clear solution to breeding in these areas.

Hummocky marshes are more common along the South Shore. This may be due to the fact that marshes along the South Shore are not subject to large sediment inputs resulting from storms because a substantial fetch, which would generate large waves capable of carrying sediment onshore, is difficult to find in this sheltered embayment, and therefore sediments are not deposited in the small voids between the marsh vegetation. Calculations conducted on the potential for tide-borne material to provide enough sediment so that a marsh can keep pace with sea level rise showed a definite shortfall in the amount of material delivered to the marsh surface. Organic material from plant detritus can contribute to the accumulation, but other inputs may be necessary (Cashin Associates, 2005a).

Input of material generated by restoration activities, applied either directly to hummocky areas via sidecasting from a ditching machine, or through various blading techniques with low ground pressure equipment, can serve as management techniques to address the natural material deposition shortfall. It is good mosquito control practice, in any case. The result of the applications would be a thin veneer of marsh sediments that fills in the areas between the clumps of vegetation. This eliminates the areas as potential mosquito breeding habitats.

There do not appear to be many greater ecological functions provided by these intermittently ponded areas. They support some aquatic invertebrates, especially those such as mosquitoes that have very quick developmental cycles (they tend to only be flooded for less than two weeks, if they are to support mosquito production [CA-CE, 2004]), and also will host a robust microbial community. However, no marsh ecology text explicitly identifies these areas as important or interesting sites on a salt marsh; in fact, the ecological function of such areas are not discussed at all, even in texts that focus on high marsh dynamics or are otherwise comprehensive treatments of salt marsh ecology (see, especially, Nixon, 1982; also see Bertness, 1997; Mitsch and Gosselink, 2000; Daiber, 1986; Dreyer and Niering, 1995; Kreeger and Newell, 2000; Pomeroy and Wiegert, 1981).

A marsh that would benefit from back-blading/sidecasting is Pickman-Remmer. The high marsh in the western segment of Pickman-Remmer is predominantly *S. patens*, creating a hummocky terrain which presents breeding habitats for mosquitoes. Some jurisdictions have noted that these kinds of applications of sediment often encourage *S. patens* to further expand into the formerly void areas. This can further reduce the overall clumping of plants that was responsible for the development of the pothole topography. Applying this technique must also be carefully planned, as, for example, spoil excavated from areas where *Phragmites* has colonized should not be spread where there is no *Phragmites*. This is because *Phragmites* can propagate from rhizome pieces. Portions of the upland border and interior marsh at Pickman-Remmer are dominated by *Phragmites.*

The application of several inches of sediments could suffocate, break, or otherwise have deleterious effects on existing vegetation. However, experience in other jurisdictions has shown the plants are limber and rapidly spring back, if already growing, or sprout through the surficial application the following spring if dormant when the work is done. The material applied needs to be dispersed with some degree of care. A potential impact would be to apply too much material in certain areas, which could raise marsh elevation locally and result in drier conditions that could encourage undesired vegetation changes. Drier marsh conditions are favorable to *Phragmites* or shrubby upland plants, such as *Baccharis halimifolia* and *Iva frutescens*. Increases in elevation at Pickman-Remmer are of special concern, given the already sturdy stands of *Phragmites* in the upper border and mid section of the marsh that could spread to other areas. A natural mitigation of this is the tendency for higher, marsh overwashing tides to even out loose sediment across the marsh surface. Several high tides following application of the materials could even out the elevations enough. This appears to be a mechanism that assists remediations in New Jersey, so that no great care is taken to ensure all applications are exactly even – "close enough" is good enough, in practicable terms.

Damage to roots can also occur if too frequent tracking of machinery across the area being treated occurs. Ruts are always a concern, even with low ground pressure equipment, and could result in standing water that creates new mosquito breeding habitats. Excessive tracking over a particular area could also damage vegetation.

Individual marsh characteristics should be carefully considered when deciding whether or not to sidecast or back-blade excavated spoil. On a marsh where the tidal range is large, such as West Meadow, located on the north shore, sediments deposited on top of the marsh surface could wash away over time with the tide. There the velocities associated with the large amounts of water that sometimes overtop the marsh may undo the careful application of the sediments. Then again, in these settings, the low marsh dominates the marsh, making the need to treat most of the marsh to fill potholes, since that terrain is not present.

BMP 9. Small (500-1000 sq. ft) Fish Reservoirs in Breeding Areas

It might be argued that this BMP represents a major impact to the existing marsh. Certainly, the construction of small ponds on a marsh represents a fundamental change in the degree of marsh management hitherto discussed. Previous BMPs may have resulted in slight alterations of the existing marsh characteristics. The construction of ponds in mosquito breeding areas of the marsh is perhaps as active a management step for salt marshes as the original construction of ditches.

On the other hand, there are many who insist that installing ponds into a grid ditched marsh is mere restoration to conditions that previously existed. It is generally not possible to determine where ponds might have naturally existed on a pre-ditched marsh that suffered drainage through ditching. However, in fairness, it is unlikely that pre-ditching ponds were all located in the high marsh in the center of intense mosquito breeding. This suggests that pond construction necessarily has some artificial components to its implementation.

The construction of small ponds and pools on the marsh surface is intended provide refuge for mosquito larvae consuming fish, predominantly killifish. These reservoirs should to be constructed in areas where potholes or breeding pannes occur and have little or undesirable vegetative cover. However, loci of breeding, even if vegetated, are suitable for ponds. Mosquito managers in New Jersey have found that the combination of small pond construction in the spots where breeding is very intense along with spoils placement onto additional, nearby breeding locations provides long-term reduction, and usually elimination, of the need to larvicide the treated areas. The impact also is aesthetic: open water reappears on the marsh, and, because there is a need for good water quality to support the fish, it is generally clean open water. Managers in New Jersey install combinations of isolated and connected ponds. Isolated ponds are generally found in close proximity to a source of tidal flooding, so that water exchanges over the surface of the marsh, and sometimes through the subsurface water table, can maintain water quality for the fish. Connected ponds are used when it is unlikely that overwashes or the saline water table will provide the quality of water necessary for fish survival. An open connection allows for twice-daily exchanges of water, to some degree, and may result in improved water quality.

A major impact from this kind of action has no direct mosquito control implications. For most Suffolk County marshes, especially those in the South Shore Estuary, increasing open water on the marsh is a major increase in habitat diversity. Many south shore marshes are depauperate in surface water. New Jersey research suggested that unditched (and so presumed natural) marshes there have a ratio of marsh surface area to open water of approximately three to one (between 25 and 30 percent open water) (Lathrop et al., 2000). This level of open water is exceedingly rare in Suffolk County, and suggests there is a deficit here. Although it is not clear whether or not the lack of surface water is natural (perhaps a function of low tidal ranges, the relatively small sizes of the mainland marshes in the South Shore Estuary, or other local factors), it suggests that there is an ecological target that management of the marshes can and perhaps should seek to attain. For example, at Wertheim National Wildlife Refuge, the amount of open water in the demonstration areas (prior to the project) was quantified as being on the order of two to four percent of the entire marsh. Not only do Refuge managers have a mandate to manage the site so as to protect and foster migratory waterfowl, but this comparison of existing surface water to more natural levels suggested that ponds and pools should necessarily be part of any restoration action. Similarly, it is likely that most analyses of the County's salt marshes will find that interior surface waters are lacking in comparison to other salt marshes of the northeast US. Increasing surface waters, by increasing habitat diversity, is likely to result in increases in general biological diversity in the marshes.

Regulators, especially those at NYSDEC, have been very cautious regarding water management projects, especially those that propose to increase surface waters in a marsh. This stems from several general considerations:

1. Jamaica Bay, which has been manipulated in many ways over the past hundred years or so, has experienced sudden losses of salt marsh. The processes driving this wetland loss are not yet completely determined. It is not clear if the wetlands are disappearing because of actions outside of the marshes that are impacting them, or because of forces acting within the marsh itself (or, some combination of the two). Therefore, it is far from clear that the condition(s) that may be causing the problem is (are) unique to Jamaica Bay. This makes regulators loathe to allow actions that may create some of the conditions found in Jamaica Bay.

2. Many natural resource specialists think many salt marshes in Suffolk County are functioning well, in terms of certain specific ecological services such as providing fish habitat. Alterations to existing conditions could lead to diminishments of this or other functionalities.

3. NYSDEC has a legislative mandate to ensure that there is no loss of salt marsh acreage. Salt marsh acreage is measured in terms of vegetated areas. Therefore, projects proposing to add to surface waters within a marsh are in potential conflict with State law.

4. Local regulators have expressed concerns that some proposed projects have not been well defined or have not had goals and objectives clearly expressed. In a sense, these regulators are concerned that some projects have been proposed merely to be "doing something," or because neighboring jurisdictions are conducting similar projects.

5. Because of a lack of dedicated resources, some past marsh manipulations have not been well-documented, and have not been shown to have met goals and objectives associated with them. Regulators do not want to allow projects to be implemented without assurances that the success (or failure) of the project will be demonstrable.

The fears regarding spreading "Jamaica Bay" disease to other salt marshes on Long Island will probably best be addressed through the success of some well-designed, well executed projects. Nonetheless, catastrophic loss of salt marshes remains as a potential impact from major manipulations of the hydrology of these systems. Many observers, while sympathetic to NYSDEC concerns, believe conditions in Jamaica Bay are unique, or are the result of anthropogenic forcings of such long duration and intensity that the probability of the same kind of marsh loss occurring in less impacted areas is miniscule.

The Wetlands Management Plan intends to address the other concerns. Major changes in salt marshes will only be made because of a well-demonstrated need. For projects SCVC initiates, most times this will be the presence of mosquito breeding that causes problems to human health and public welfare (although flooding issues will be a source of certain projects, as well). Appropriate monitoring and reporting on the effects of each project is a necessity; to ensure adequate resources are available for this work, the County is soliciting assistance from partners on these projects, such as local municipalities, NGOs such as The Nature Conservancy, the Long Island Wetlands Restoration Initiative and Ducks Unlimited, and major government property owners such as FINS and USFWS. The County also hopes that NYSDEC will locate resources to assume its role in terms of wetlands management and resource inventory work, which may allow for post-project monitoring participation.

An example of a marsh that would benefit from the creation of small fish reservoirs is Namkee Creek. Small fish reservoirs are preferred at Namkee Creek because the marsh is relatively small in size (26 acres) and has a low tidal range. Numerous small ponds and pannes already exist throughout the mid section of the marsh. Clumps of *S. patens* and *S. alterniflora* vegetation are present throughout the ponds and pannes, providing habitats for mosquitoes to breed. Most of the ponds and pannes are too shallow to provide adequate refuge for mosquito consuming fish, with depths ranging from 10 to 20 cm deep. Generally, ponds created for fish habitat have a maximum depth of 30 to 36 inches (80 to 90 cm), to provide a reservoir so as to keep the fish on the marsh and alive during low tide (although by no means should the entire pond be as deep, as shallower "lips" and edge areas provide good foraging opportunities for shore and wading birds). By altering depths and structure of the existing ponds and pannes, fish habitat will be enhanced and fish diversity would increase. In addition, the removal of vegetation clumps would decrease mosquito habitat within these areas.

The excavated material from the ponds could be used for other restoration techniques, such as filling ditches or potholes that breed mosquitoes. In conjunction to providing habitat for larvivorous fish, the creation of small ponds will provide a valuable habitat for ducks, shorebirds, and wading birds (see Taylor, 1998).

A negative impact that may be associated with the creation of small ponds is the minor loss of vegetation that existed in the ponds and pannes. On marshes where small ponds are created in fully vegetated areas, the conversion to open water may result in different and possibly lower values.

Captree West is also an ideal candidate for the construction of small ponds. Numerous salt pannes exist throughout the marsh where mosquito breeding occurs. Deepening these pannes would enhance fish habitat and reduce mosquito production without sacrificing vegetation. Captree West, however, also has a great deal of open water already. It is sometimes used as an example of waterfowl resource supporters of the kind of marsh aesthetic that should be the goal of future restoration. For that reason, the area of open water at Captree West should be quantified, and careful considerations made if the addition of more open water is in accord with overall design goals. If not, then alternate means of addressing mosquito breeding in the pannes should be undertaken.

Heavy machinery is required for the construction of ponds. Even with low ground pressure equipment, damage to roots can also occur if too frequent tracking of machinery across the area being treated occurs. Ruts are always a concern and could result in standing water that creates new mosquito breeding habitats and could also damage vegetation.

Class III: Major Impacts

BMP 10. Break Internal Berms

In some instances, substantial levees, berms, roadways, or dikes have been constructed that hydraulically isolate part or all of a salt marsh from inundation associated with tidal flow. This isolation impacts water quality, resulting in an unsuitable habitat for killifish and other mosquito consuming fish as well as possible shifts in vegetation patterns. Intentional isolation of salt marshes from estuaries has been identified as a major environmental impact of past coastal practices (Fell et al., 2000). In Connecticut, for example, a major emphasis of salt marsh restoration has been and continues to be the estuarine reconnection of these tidally-isolated marshes.

This must be understood to be a major undertaking. The action involves a reconfiguration of societal goals, as at one time it was acceptable to construct the barrier that is now proposed for removal. Often the berm or levee was installed for flood protection purposes. Breaching the barrier suggests an assumption of a degree of flood risks in exchange for habitat improvement in the marsh.

For mosquito control purposes, the benefits are clear. Better water quality means more efficient control of mosquitoes by fish. Anecdotally, SCVC has found there is a strong correlation between good tidal circulation (and presumably better water quality) and less mosquito breeding (all other factors considered).

These formerly-connected wetlands are often assessed as degraded habitat. These are often areas that are largely overrun by *Phragmites*, for example. A lack of circulation can lead to eutrophification, including resultant noxious algal blooms, which negatively impacts salt marsh vegetation. Vegetation shifts away from patterns that would result from tidal controls have been observed, and associated with nutrient additions to the marsh (Bertness et al., 2002).

Blockage of estuarine connections necessarily limits exchange between estuarine life and the marsh. Such marshes will have limited estuarine nursery values, and will not serve as sources to the estuary for needed resources. The latter has been identified as one of the more important functions of salt marshes (Odum, 2000).

Therefore, reconnection of an isolated marsh to the estuary should cause major impacts to the existing state of the marsh. These impacts may be positive:

- reduction in mosquito breeding due to the creation of better fish habitat
- reduction of *Phragmites* extent due to increased marsh salinity
- drainage of water that may accumulate behind the barrier, which may encourage spread of high marsh plants that otherwise might find conditions too consistently wet
- access by estuarine nekton to the marsh, for nursery and other habitat needs

The impacts may also be negative, or, of an undetermined status:

- increased threat of flooding because of increased tidal amplitudes within the marsh
- potential shifts in vegetation patterns, including potential changes from fresh to salt marsh, or changes from low to high marsh (or vice versa)
- loss of wetlands due to drainage of accumulated water behind the barrier
- overall changes in local hydrology, leading to impacts that are difficult to forecast, such as changes in the long-term state of the existing ditch network, which could lead to the creation of additional (or fewer) mosquito breeding sites, etc.

The salt marsh at West Watch Hill is an ideal candidate for breaching berms in an effort to restore tidal flow. West Watch Hill is a 23-acre grid-ditched salt marsh located on the Fire Island barrier island, in the Town of Brookhaven, within FINS. *Phragmites* has invaded most of the marsh, leaving only a small interior section of mixed high marsh and low marsh vegetation. Many small and large ponds exist throughout the marsh, with few to no fish. The standing water within the marsh is extremely murky and of generally poor quality. A large berm exists along the northern boundary of the marsh restricting tidal flow in and out of the marsh except during extreme weather events. As a result, groundwater has been accumulating on the marsh making it become relatively fresh (salinity readings in ditches ranged from 0.5 to 1.2 ppt during a November 2004 site visit). By breaching this berm, tidal surface water exchange between the marsh and the estuary would be significantly improved. In turn, this would enhance fish diversity and access to mosquito breeding sites, as well as prevent the stagnation of water where mosquitoes are likely to breed. Waterlogging of soil and loss of high marsh vegetation may also be prevented by breaching the berm, as the marsh would have the ability to drain the standing fresh water. Salinity is a known stressor to *Phragmites*, therefore if more saline water reached the back of the marsh, expansion of *Phragmites* would be controlled and its extent possibly reduced (see Bart and Hartman, 2002).

Breaking berms will affect the existing hydrology of a marsh. Any time in which hydrology is altered on a marsh changes in vegetation are likely to occur. Breaching the berm at West Watch Hill will possibly drain existing ponds and pannes. Breaching berms to increase tidal flow may cause flooding of adjacent uplands; therefore, berms should not be breached on a marsh where there is a possibility of flooding upland areas. Since West Watch Hill is located in an area with essentially no residents (only five residences within one-half mile), flooding would not be a significant concern.

On the contrary, at the Pickman-Remmer marsh, breaching the berm on the eastern segment of the marsh could possibly cause more negative impacts. Breaching the 1.5 meter berm along the eastern boundary of the marsh would restore tidal flow; however, the existing ditch network could cause flooding of adjacent residential properties during storm tides. Three existing culverts breach this berm, but the existing tidal exchange is not sufficient, based upon the extent of *Phragmites* throughout the marsh and the lack of wildlife. This marsh is in need of tidal restoration; however, a more appropriate technique would involve increasing the size of the culverts and altering overall marsh hydrology to transport tidal water to the back of the marsh.

Heavy machinery is required for breaching large berms. Even with low ground pressure equipment, damage to roots can also occur if too frequent tracking of machinery across the area being treated occurs. Ruts are always a concern and could result in standing water that creates new mosquito breeding habitats and could also damage vegetation.

BMP 11. Tidal Channels

Tidal channels (salt marsh creeks) are integral features in most salt marshes. They are extremely valuable for the marsh in terms of creating connections to the estuary, both for transport to the marsh as well as to transport from the marsh (Odum, 2000). They are extremely productive fish habitat, comprising the parts of the marsh where estuarine fish often come to predate on marsh resident fish (Deegan et al., 2000). Tidal channels are essential for maintaining good water quality in the interior of the marsh, and so are important for maintaining killifish habitat. They serve as important edge habitat definers. Tidal creeks transport estuarine water into the marsh interior, and can facilitate the removal of accumulated water from the marsh. Their sinuous character is aesthetically pleasing, and helps define the character of the marsh, through the establishment of water-marsh surface interfaces. The sinuosity of the creek also defines a series of microhabitats, which can increase the use of the creek by diverse species, and so improves the ecological character of the marsh as a whole.

Marsh creeks and tidal channels are often lacking in Suffolk County wetlands, especially on the south shore. The disappearance of creeks and creek complexity is said to be the signature of marsh maturity (Odum et al., 1979), although this may not be the case for these marshes. In any case, there are often good reasons to install tidal creeks as part of a restoration project. It facilitates the transport of seawater into back marsh areas. Tidal channels are likely to be important for certain wildlife habitat-enhancement projects, especially those seeking to improve estuarine fish access to the marsh, and to improve water quality in the interior areas of the marsh.

Constructed tidal channels taper from the estuary to the back of the marsh, and contain meanders, wider portions of channel, and potentially narrower stretches. Constructed tidal channels will often develop their own “fingers” (dendritic channels) and morphology through exposure to the natural tidal regime over time (Simenstad and Thom, 1996).

A tidal channel was created at a salt marsh in Wertheim National Wildlife Refuge in 2005, as part of the OMWM demonstration project there. The tidal channel is expected to serve as a fish habitat as well as a conduit to allow fish access to the upper marsh, and to conduct good quality estuarine water into the interior of the marsh. It is to serve as a replacement for filled mosquito ditches in conveying water from the estuary to the back of the marsh. In fact, it is anticipated that the channel will perform better at this function than the often sluggish ditches did. More estuarine water will be helpful in promoting better water quality to ensure fish presence in the high marsh. The tidal channel is also expected increase the soil salinity to favor native salt marsh vegetation and control the existing *Phragmites*. Construction of the tidal channel generated spoils. Some of the spoils were used to fill potholes and depressions serving as mosquito breeding areas and existing grid ditches. Other spoils, contaminated by *Phragmites* rhizomes, were sidecast into exiting *Phragmites* marsh. The project is too new for definitive results, but a sea robin (*Prionotus evolans)* was seen in the channel, and killifish populate ponds connected to the channel. Blue crabs, jellyfish, and several species of baitfish have also been seen either in the channel itself, or in the connecting waterways and ponds near the channel. Tidal flow in the channel tends to be brisk.

Possible negative impacts associated with the creation of tidal channels largely stem from the potential to create major changes in marsh hydrology. Design of the channel needs to be made carefully. Use of models to determine acceptable channel sizes and shapes would appear to be enlightened, as the channel must transport water without excessive loss of energy. Construction of a new channel into unserved areas always runs the risk that it will drain the water that defines the wetland. Construction of channels on the marsh fringe has the potential of intercepting groundwater, and either freshening too much area near the channel, or diverting fresh water from its natural places on the marsh (this is generally not perceived as a negative, however, given suspicions regarding the role of fresh water in the spread of *Phragmites*). The channel could be so successful that it promotes some flooding of drier land, or converts fresh water marsh to brackish or tidal vegetation. If there is any input to the marsh due to run-off, installation of a channel along the upper marsh edge can result in express transport of the inputs to the estuary, with potential negative water quality impacts from land-based pollutants.

Tidal channels are used as a supplement to other efforts to control mosquitoes, as in and of themselves they are unlikely to have major impacts on breeding. They can help create better water quality to support mosquito larvae consuming fish, but generally are not constructed directly into breeding areas.

An example of a salt marsh where creating a tidal channel may result in more negative than positive impacts is West Meadow. The tidal range at West Meadow is large and the existing ditch system transports estuarine water to the back marsh. No vector control problems exist at West Meadow and fish and wildlife actively utilize the marsh. The creation of a tidal channel at West Meadow could lead to an increased amount of flooding to the upland and adjacent roadway, as flooding is already an issue during spring and storm tides. Excessive flooding or drainage caused by a tidal channel may also result in undesired vegetation changes.

Heavy machinery is required for the construction of tidal channels. Even with low ground pressure equipment, damage to roots can also occur if too frequent tracking of machinery across the area being treated occurs. Ruts are always a concern and could result in standing water that creates new mosquito breeding habitats and could also damage vegetation.

BMP 12. Ditch Plugs

The suite of actions that can replace the use of standard water management (ditch maintenance) has been called Open Marsh Water Management (Ferrigno and Jobbins, 1968). However, on Long Island, the only kind of OMWM that has ever been installed has been ditch plugging (Lent et al., 1990; Niedowski, 2000). On Long Island, there is sometimes an identification of ditch plugging with OMWM, although OMWM encompasses many more kinds of water management techniques besides plugging the ditches. That is why this document has tended to identify the proposed water management activities "progressive water management" rather than OMWM, to avoid focusing the discussion on ditch plugging to the exclusion of other BMPs.

Ditch plugs are intended to raise the elevation of the tidal inundation in the marsh and reestablish natural pools and pannes in the marsh surface (Taylor, 1998). Ditch blockages create the greatest degree of fish refuges by isolating all of the refuges from the daily tidal circulation; this technique is also intended to most fully restore water tables that may have drained due to ditch construction. These dams are usually installed at the mouth of the ditches, and are most effective if constructed 50 to 100 feet long. This technique is intended to restore the pre-ditching water regime by elevating the water table that may have been drained by the ditches (Dale and Hulsman, 1990).

Ditch plugs create a closed system, allowing tidal exchange only during spring or storm tides. Generally, closed systems seem to be best suited for higher tidal regimes where surface water losses from drainage at tidal lows may be a grave concern. Adequate water quality may be maintained within the system despite infrequent inputs of tidal water because of the vigorous flushing associated with the large tidal prisms. Open systems of one kind of another may be best in the lowest tidal ranges where marsh interior water quality is the key issue.

The grid-ditched salt marsh in the northern section of Pipes Cove would be a suitable location for installing ditch plugs. This section of the marsh is tidally restricted via a culvert pipe located underneath the LIRR train tracks. The higher water table created by plugging ditches may result in a reduction of potential mosquito habitat through oviposition disturbance. The ditch plugs would serve as fish reservoirs (James-Pirri et al., 2001) and would enhance refuges for fish from wading bird predation by providing adequate protective depths. In addition, ditch plugs would create a tide cycle-proof habitat that would allow fish to remain in proximity of mosquito breeding locations, whether or not the ditches would drain at low tide absent the plug. Ditch plugging may also create more surface water on the marsh, which can enhance natural resource values. The potential of polluted runoff from upland sources fed into the estuary through ditches may be reduced as a result of plugging ditches. This is because ditch plugs increase the amount of water retention time in the ditches which could enhance any polishing impacts that occur within the marsh. The Town of East Hampton has installed ditch plugs to reduce coliform exports from some marshes (high coliform levels lead to closures of shellfishing beds), and the Town has reported that anecdotal findings indicate it has been a successful strategy.

There is a possibility of retaining too much water on the marsh associated with ditch plugs, resulting in vegetation changes and flooding of upland areas. NYSDEC, as discussed earlier under BMP 9, has reservations regarding the long-term effect of retaining more water on the marsh, fearing marsh degradation may result.

The retained saline water and increased height of the water table resulting from ditch plugging are thought to be effective for *Phragmites* control, however (Bart and Hartman, 2002). This is based on the concept that the water in the ditches will tend to be saltier than unimpounded ditch water. This originates from the notion that salt water is denser than fresh; therefore, if there is any density separation between salty estuarine water and fresher inputs, the fresh water will be more buoyant and drain over the top of the plug first. An alternate understanding of ditch hydrology is that the collection of fresh water behind the plug may lead to freshening of the marsh, and so potential *Phragmites* expansion. Most anecdotal evidence supports the idea that plugs promote saltier retained waters (despite the shabby theoretical underpinning to salt water retention behind the plugs).

Closed systems are not recommended on marshes where the tidal range is low and residential areas are dense, such as is the case for most marshes along the South Shore. Less vigorous tides on the South Shore could result in the stagnation of retained water on the marsh. Open systems would be more beneficial and would improve water quality through daily tidal exchange. Most of the mosquito control ditches at Wertheim NWR were plugged at various times in the 1980s and 1990s. The ditch plugs were constructed with small pieces of plywood, about three feet long, placed in the ditch with marsh material placed behind it. These plugs did not effectively lower the number of mosquito production on the marsh, as measured by the continuing need for aerial larviciding there. Due to the relatively small size of the plugs, many have failed, either due to physical processes (erosion caused by tides or storms) or undermining by muskrats.

Sills plugs are a type of ditch plug that is constructed to a level just short of the marsh surface. They are intended to retain water in the ditch, and thereby prevent dewatering. Sills are often used in areas of large shallow salt pannes to create a semi-tidal OMWM system, where a small four to six inch rise and fall in accordance with daily tides is created within the ponds and spurs. Sills are usually 50 to 100 feet long and are placed at or near tidal ditch outlets to a depth of approximately four to eight inches below the high marsh surface (Taylor, 1998). Sills allow excess ephemeral sheetwater to be removed from the marsh surface during ebb tides, while maintaining the subsurface water table level (Lesser, undated[1]). This method supports fish habitat on or near the surface of the marsh while still allowing for more water and nutrient exchange with the estuary compared to a closed or non-tidal system. Sill ditches that have a gradual slope are less desirable in high marsh areas because they will result in the lowering of the marsh's tidal and semi-permanent water levels (USFWS, 1998).

Sills are a common practice on Connecticut salt marshes. They are used to connect ponded areas to breeding sites. This technique, combined with full ditch plugs and constructed areas of open water, has successfully reduced the amount of mosquito breeding to a level where it is no longer necessary to apply larvicides (Paul Capotosto, CDEP, personal communication, 2003).

Heavy equipment is required for the construction of ditch and sill plugs. Even with low ground pressure equipment, damage to roots can also occur if too frequent tracking of machinery across the area being treated occurs. Machinery could also possibly damage the structure of the sides of the ditch during times when the marsh is excessively wet. Ruts could result in standing water that creates new mosquito breeding habitats and could also damage vegetation.

BMP 13. Ponds above 1,000 sq. ft for Wildlife Value

The construction of artificial ponds provides permanent open water habitat on high marsh areas. BMP 9 discussed the general impacts of this process. The ponds discussed in BMP 9 were smaller ponds, intended to provide fish habitat in mosquito breeding locations. In some instances, however, larger ponds may be in order.

For one, larger ponds tend to provide the kinds of habitat features desired by waterfowl. This means that waterfowl can be better supported by building fewer larger ponds than many smaller ponds. The birds need adequate space to land and take wing, and also prefer more open water as protection from shoreline predators.

Secondly, research in New England has shown there tends to be a general size distribution of ponds in unmodified salt marshes. There are often several large ponds in moderate sized marshes. Constructing only small ponds, therefore, does not accord with this size distribution, and suggests that adequate habitat diversity may not be met.

Third, people often find larger ponds to be aesthetically more pleasing.

Most reports find that marshes altered with extensive networks of pools are utilized by larger bird populations than grid-ditched marshes that have few pools (Reinert et al., 1981; Clarke et al., 1984; Brush et al., 1986; Adamowicz and Roman, 2002). Thus, large ponds can improve or restore waterfowl habitat. Montgomery (1998) concluded that the OMWM alterations at

Rumney Marsh in Massachusetts, which included the construction of ponds, dramatically enhanced or restored wading shore bird and waterfowl habitat.

Large ponds may be suitable for the salt marsh at West Gilgo Beach. West Gilgo Beach, a salt marsh approximately 300 acres in size, is located on Jones Island just west of Gilgo State Park. Ditches at this marsh have been ditched every 60 meters and run perpendicular to Great South Bay. The current ditch system leaves the ditches dry or stagnant during low tide. These stagnant ditches provide an opportunity for *Phragmites* to expand from the southern boundary of the marsh since it is known to outcompete other vegetation in shallow, stagnant waters (see Niedowski, 2000). Mosquitoes are known to breed near the southern border of the marsh; therefore, installing a large pond in this area would increase fish habitat and access to breeding sites, and increase soil salinity that will prevent *Phragmites* expansion. Ancillary benefits include an increased habitat for ducks, shorebirds and wading birds (Taylor, 1998). Spoil from pond excavation can be used to plug some of the ditches that are not transporting tidal inputs effectively. Filling the ditches will serve as mitigation for the loss of vegetated tidal wetlands from the construction of the pond.

Crab Meadow would also benefit from the creation of a large pond. Since Crab Meadow currently does not actively breed mosquitoes, the pond would be geared towards enhancing wildlife. The spoil generated from the pond could be used to fill some select ditches, or areas of ditches, allowing a more natural, aesthetically pleasing marsh.

Potential negative impacts associated with the creation of large ponds should be considered prior to implementation. Heavy equipment is required for this technique and repeated equipment passages over the same areas of marsh can lead to rutting and cause damage to plant root structures. Whenever vegetation is converted to areas of open water, different and possibly lower values may result. Furthermore, the construction of larger ponds may create conflicts with existing State regulations and federal policies regarding "no net loss" of tidal wetlands. Small ponds, as constructed in New Jersey, blend in quietly with the vegetated marsh, and do not explicitly call attention to what may be, when all accounting is done, a loss of tidal wetlands. Larger ponds are much more visible and strikingly obvious signs that, potentially, the amount of vegetated wetland has been reduced.

BMP 14. Filling ditches

For many, salt marsh restoration requires undoing the grid ditching of the 1920s and 1930s. Although the impacts of ditching are probably not as great as some fear, and there are benefits to some important marsh functions provided by ditching (see the discussion of BMP 4, above), there is also no doubt that rote grid ditch installation was a very blunt tool to address a fairly subtle salt marsh issue, something that was recognized even in the first instances of its application to the problem (Smith, 1904 [out-of-print and unavailable; as quoted by Wolfe, 1996, and confirmed by Crans, Rutgers University, personal communication, 2004]).

More progressive means of salt marsh management recognize the importance of using fish predation to control mosquito larvae. The perspective of 75 years ago was that engineering solutions must be more robust than biological manipulations. Thus, the focus of ditching was to remove mosquito breeding habitat by altering hydrology. This was successful in achieving its end in certain setting, achieved its end in other settings but only because of secondary effects (improved fish access), and failed in others. The ditches also have often required ongoing maintenance. Alternatives to ditching, discussed above, hold the promise of not requiring as much (if any) maintenance, and also appear to be more effective (according to the experiences of other jurisdictions).

For these reasons, and for the aesthetic improvements that can result, it can be possible to undertake progressive water management to address mosquito control problems and other marsh management issues, and include ditch filling as part of that project. The intent of ditch filling is to remove the visually intrusive grid ditched system, and to restore the marsh to earlier, pre-ditch conditions. However, restoring a marsh by filling ditches alone is difficult to conduct without other remediation activities. For one, it may foster mosquito problems (even if non-existent at this time) or allow them to become worse (ditches have some effectiveness as water management means). Secondly, the spoil for the ditch filling needs a source. The best material for this purpose would be salt marsh sediments, generated by some purposeful excavation in other areas of the marsh. Ditch filling will, therefore, need to be accomplished in combination with an alternative water management system such as tidal creeks and/or ponds, as these can generate the large quantities of fill needed.

West Gilgo Beach is a good example of a salt marsh that would be suitable for filling ditches. If large ponds were constructed at this marsh, the spoil material could be used to fill stagnant or occluded ditches, eliminating mosquito breeding habitat. Vegetation that was lost due to ditching would be reestablished, and possible pollutant conveyance across the marsh from the parkway would be reduced. However, with ditch filling, tidal circulation and fish access would be reduced, and ditch habitat would be loss for wildlife using the ditches. Fresh water from precipitation may be retained on the marsh if the ditches were effective at draining it off the marsh surface, resulting in vegetation changes to species that prefer less saline conditions, such as *Phragmites*. If fresh water is retained on the marsh at West Gilgo subsequent to ditch filling, *Phragmites* along the upland border may invade the interior marsh. Vegetation drowning may also occur if excessive water remains on the marsh surface. There is the possibility of creating new mosquito breeding habitats if ditches are not properly filled, or if filling leads to the creation of new habitats by making the marsh wetter, or by restricting fish access to breeding locations. Thus, other hydrological alterations need to be considered as well, such as channel construction to ensure there is adequate tidal circulation and fish access to the pertinent areas of the marsh. The balance of materials needs to be carefully determined, in order that enough spoils are generated to fill the ditches, without too much excess material. At the Wertheim demonstration project, partly because ponds were made larger for natural resource augmentation purposes, and partly because there were so many breeding areas, there was an excess of material generated through pond construction, beyond that needed for ditch filling. The excess material was back-bladed into breeding potholes and pannes, so that no off-site disposal was required.

Ditches should not be filled with *Phragmites*-contaminated spoils. That will only lead to spread of the invasive plant through clonal growth from the rhizomes. At Wertheim, it was possible to reserve the upper layers of sediment removed from the ponds, which were presumably richer in rhizomes, seeds, and roots of the native vegetation. These upper layers were used to top off the ditch filling in many cases, to promote rapid revegetation of the former ditches. Exactly which vegetation to use preferentially at these sites is not easy to determine. *S. alterniflora* (and *Phragmites*) were often found in thin sections along ditch banks, even in predominantly high marsh areas. These former waterside locations will now be interior locations following ditch filling, so the use of (say) *S. patens*-laden spoils from a pond area is not inappropriate. This does suggest that vegetation reorganization may be expected following such massive changes in the hydrology of the marsh.

If the marsh has been effectively drained by the ditches, then filling the ditches may lead to standing water due to a higher water table. If this project has correctly evaluated local hydrological conditions, this is more likely to be the case under higher tidal ranges, such as along the north shore. If ditches are filled at such marshes, monitoring should include a water table evaluation and careful surveys for standing water. If standing water appears, then follow-up work could include spot installation of ponds to collect the water in less mosquito-friendly environs, or the use of spur ditches to address localized problems. Benefits associated with a higher water table include the reestablishment of natural ponds and pannes, with better habitat for waterfowl, and potentially better habitat for muskrats (Bourn and Cottam [1950] found that muskrat trapping records showed declines following ditching, suggesting the muskrats did not fare as well after ditching) and other creatures (seaside sparrows were thought to find ditched marshes less appealing, perhaps due to increased predation opportunities for foxes and raccoons caused by the drier marsh [Greenlaw, 1992]).

It is probably appropriate to monitor for standing water under all hydrological ranges, as the standing water may be localized, and due to other factors than rising water tables. Causes could include uneven settling of the fill, the creation of impermeable lenses, or ruts and other construction impacts.

It is difficult to justify the filling of ditches strictly from a mosquito control perspective. Benefits to ditch filling are aesthetic, and in some instances, ecological (if it is believed that the ditch construction led to consequential changes in the marsh), although there is a school of opinion that the ditches themselves constitute valuable habitat. Filling ditches can be justified on a materials management basis in some cases, but often the determination will need to be made outside of the limited perspective of source control for mosquito management.

Several types of low ground pressure heavy machinery would be needed to fill ditches. These include machinery that generates excavated spoil from a source, a dump body to transport the spoil to the ditch, and an excavator to properly fill the ditch with the spoil. Damage to roots can occur if too frequent tracking of machinery across the area being treated occurs. Ruts created by equipment could result in standing water that creates new mosquito breeding habitats and could also damage vegetation. If the ditches are not filled properly, areas of standing water could result or, if filled too high above the marsh surface, berms could result. Improper sequencing of ditch filling, such as filling in ditches from the mouth towards inland, could result in the entrapment of water in the upper portion of the ditch and surrounding area, which could make filling difficult and could damage vegetation.

BMP 15. Dredge Material Removal

Dredge materials are often unsuitable for disposal in marine environments (such as for use in beach restoration) and often long distance transportation to off-shore disposal sites is inconvenient or expensive. As a consequence, local disposal of dredge materials was undertaken for particular projects. The least valuable land in the vicinity of project sites was often salt marshes. Many island and other marshes therefore have a burden of dredge material from less enlightened times.

Dredge spoils usually consist of uneven topography that supports mosquitoes (often those associated with the upland fringe, such as *Ae. vexans*, the floodwater mosquito, rather than the classic salt marsh mosquito). The removal of dredge spoils to restore a marsh to a more standard marsh vegetation regime is a major earth-moving operation. The spoils can be dug up and relocated. Often, the saturated conditions that made management of these materials so difficult years ago have long since been resolved (i.e., dewatering has been completed for many years), and so alternate disposal sites may be available at this time. The initial phase of the project will therefore require the removal of the dredge materials.

This will result in the loss of vegetation that has become established on the spoils. Often, these are plants that have lesser ecological value, such as shrubby, weedy trees and *Phragmites*. Care must be taken that plants that grow in disturbed situations do not include species of special concern, or constitute habitats for other threatened species. Examples of rare or endangered species that prefer disturbed ground include sandplain gerardia (*Agalinis acuta*), and piping plover (*Charadrius melodus*) (neither one of which, it should be noted, colonize upland dredge materials areas). In addition, the site to which the spoils are to be removed should be examined to ensure no negative impacts will be experienced there. The disposal of the spoils will most likely be limited to upland disposal, since beneficial reuse opportunities for such materials are generally limited.

Since dredge spoil piles are almost never in intertidal areas, but rather in the irregular flooded area that constitutes potential high marsh, the classic restoration would involve plantings of *S. patens*. Restoration of marshes from bare ground is difficult, with successes occurring often, but failures also being common. The restoration is likely to succeed when hydrological issues can be satisfactorily resolved. This potential is thus enhanced when a restoration is additive to an exiting area of marsh, so that conditions in the natural marsh can be extended into the restoration site.

Gilgo Island, located in the western reaches of Great South Bay, is a 273 acre marsh with approximately 40 acres of uplands created from dredge spoils excavated from the adjacent navigation channels in the bay. The dredge spoil upland habitats are located in the western portion of the marsh and surround a low lying, water retaining area. The removal of these spoils would reduce the number of mosquitoes breeding in these areas, and convert the low value upland to a more valuable wetland habitat. Dredge spoils are also noted to impede water flows. Therefore, tidal exchange is likely to be enhanced to the areas of open water which in turn, would increase fish and wildlife diversity and habitat. It is possible that the removal of the dredge spoil will result in the drainage of these ponds, so combined alterations may be needed to minimize impacts. The removal of these spoils would also be more aesthetically pleasing. However, the removal of dredge spoil may result in the creation of new mosquito breeding habitats since most dredge spoils areas would be restored to high marsh vegetation where mosquitoes are more likely to breed.

Heavy machinery would be required for the removal of dredge spoil. Damage to root structures may occur even with low ground pressure equipment, if too many trips over the same area occur or if the equipment is used during times when the marsh is excessively wet.

Interim Actions/On-going Maintenance Activities

It will not be possible, following initial evaluations of the conditions at various salt marshes in the County, to ensure that the BMP most appropriate for the marsh can be installed immediately. In fact, in some cases a rather long time period may be required before the BMP can be undertaken. Fiscal realities and equipment scheduling may lead to some delays (although it is anticipated these will be relatively short-term under most conditions). Other factors that may affect the ability to conduct a BMP would be landowner unwillingness or uncertainty regarding the proposed project, and, in some instances, failures to conduct necessary public planning processes. This is an issue for the many New York State Tidal Wetlands in the County. Prior to undertaking major restoration activities there, Unit Management Plans need to be adopted by NYSDEC. It is unclear if each wetland is required to be assessed separately, or if the holdings can undergo a single unified review. It is clear that this public process generally requires a year or more to complete when full attention is given to the process. Given staffing realities and program priorities, it is unlikely that the State wetlands will undergo this planning process in the very near future.

Therefore, four Interim Management/Ongoing Maintenance Actions (IMAs) have been identified. These are generally not to be the optimal BMPs for the wetland to which they are applied. The presumptive interim action is to allow natural process to occur (marsh reversion). The three other IMAs provide SCVC with a means of providing a degree of progressive water management on an interim basis, where required, until the necessary steps can be taken to conduct more appropriate BMPs at the salt marshes. Impacts are of a magnitude with the associated BMPs discussed above. The impacts associated with the IMAs may be less due to anticipated time of implementation, or may be greater, due to suboptimal fit with the problem at hand. The discussions below are intended to address both of these concerns.

IMA 1. Natural Processes (No action/reversion)

There are two clear reasons for identifying reversion as the presumptive interim management policy for County wetlands. One is concordance with the philosophical position that non-intervention as an environmental policy often leads to striking environmental benefits. This is an axiom by which National Parks are managed, for example. In many cases, due to inadequate system knowledge or poor theoretical applications, well-intentioned active management efforts have led to unintended negative consequences. This is often true for complex systems that are experiencing severe stresses. This appears to be the case for at least a subset of marshes within the County. Allowing for a period of recovery may lead to better overall health for some of these systems.

Secondly, reversion is an excellent interim management policy because it is the one management method that can always be undone (successfully undone, that is). This may not be the case for other, active management means, which may or may not be reversible (most generally are only reversible with great effort, and generally not reversible back to the exact starting point prior to the project).

There are the potential for many negative impacts with reversion. Major monitoring efforts will be undertaken for mitigation. Monitoring, using remote sensing, will quantify the total vegetated area for these marshes, and also make quantified measurements of general vegetation types (low marsh, high marsh, mixed vegetation areas, and *Phragmites* areas). If trends emerge from these measurements, the marshes will be evaluated to determine if reversion is causing negative impacts to the health of the marsh. If it is, then alternate interim or long-term restoration management plan will be selected for the site.

An example where reversion could be used as an interim management action is West Meadow. The marsh tends not to breed mosquitoes, due to the small high marsh extent. Thus, allowing natural processes to occur is unlikely to cause a mosquito breeding problem. Until the Town of Brookhaven and the Ward Melville Heritage Organization determine joint priorities for long-term restoration of the marsh, it is better to allow for reversion (assuming no negative trends in vegetation patterns ensue, such as loss of vegetated tidal wetlands, or expansion of *Phragmites* extent).

IMA 2. Selective Ditch Maintenance (Standard Water Management)

Impacts associated with ditch maintenance have been extensively discussed under BMP 4. Under certain conditions, selective ditch maintenance will be implemented at areas where water management is required, but no permanent management technique can be immediately applied. The intent of this maintenance will be to make the ditches more effective over an interim period. This means that the need may be to drain some persistent standing water, or to increase tidal circulation to allow fish access to a breeding area. A possibility is to also deepen areas behind blockages in a ditch, if it is determined that adequate water quality exists to support fish, but predation on the fish is limiting their effectiveness.

Additionally, through careful observation, under selective ditch maintenance it would be determined if some simple modifications to the existing ditch system, such as widening the mouth of a particular ditch, or blocking flow from one area of the marsh to another, could change the forces that resulted in the conditions that created the need for the current maintenance.

Existing water management systems (ditches, culverts, and other structures) will normally be either left alone, if not needed for mosquito control, or upgraded to BMPs as outlined in the Plan. In some cases, implementation of BMPs is not immediately feasible due to lack of pre-project information or institutional factors such as landowner policies. Implementation of BMPs may also not be immediately feasible due to lack of resources. For instance, if major tidal flow restoration is desirable but is currently too expensive because it involves major road work, interim measures should be taken while these resources are sought if the alternative is a loss of habitat and/or an increased reliance on pesticides.

Assuming Long-Term Plan water management policies are implemented (especially progressive water management, as discussed here), the general presumption will be against maintenance of ditch systems. However, in limited circumstances, existing structures may be maintained on an interim basis, when the following conditions are met:

- Deterioration of or damage to structures is resulting in a significant mosquito problem, as evidenced by larval and/or adult surveillance, serious enough to require control. An example would be a collapsed pipe that restricts tidal flow and results in a need to larvicide an area. Or:
- Failure to maintain the structures would result in the loss of resource values, such as fish passage or tidal flow, or loss of vegetation due to fresh water impoundment. Or:
- Failure to maintain the structures would result in a hazard or loss of property as a result of flooding.

Benefits to be expected from the work include:

- Maintaining or reconstructing the existing structures will improve water circulation or provide fish habitat sufficient to reduce the need for pesticide application.
- Maintaining the structures is compatible with habitat values that existed prior to the failure or deterioration of the structures.
- Maintaining the structure will prevent flooding or other hazards.

Constraints on any maintenance of a pre-existing ditch system include:

- The structures will be maintained essentially in-place and in-kind.
- Disruption of wildlife habitat due to construction will be minimized by limiting work areas and/or by using seasonal constraints.
- Listed species will not be adversely impacted.
- Interim maintenance will not lead to excessive drainage that would result in a loss of wetlands values.
- The action will not lead to increased or more direct conveyance of inputs from storm drains or other structures.
- The action will not preclude the implementation of BMPs when resources and/or institutional considerations allow.

The primary impact from this action is the continuance of impacts associated with the installation of the ditch system. Maintenance activities can impact biota in the ditches, but that impact can be mitigated by restricting activities to times when the ditches are not used as much (late fall, winter, and early spring). Continued maintenance of a ditched marsh also obviously precludes allowing natural processes to determine the fate of the system.

An example of a situation where interim maintenance of a ditched marsh might have minimal impacts is Captree West. Several ponds and pannes exist in the interior high marsh and are connected to main ditches directly or via spur ditches. In order to maintain adequate tidal flow to allow fish access to these ponds and pannes, the tidal creek and ditches leading to them must be free of debris or other occlusions. If these ditches were to become clogged, preventing tidal flow to and from these ponds and pannes, they are likely to become stagnant and breed mosquitoes

(Balling and Resh, 1983). Minor problems could be addressed in this fashion while longer term planning determines what the optimal management of this marsh might be.

IMA 3. Culvert Repair/Maintenance when Tidal Restrictions are Apparent

BMP 5 discussed the impacts that can occur when an improperly sized culvert is replaced by one that can address the water flow problems adequately. There may be circumstances where replacement in kind is the only permissible action – whether because of permit issues, or difficulty is arranging for ancillary work (road or rail repairs), etc. In those situations, it may be that undersized or incorrect existing water control structures at a salt marsh would be cleaned and maintained in order to alleviate the immediate problem. It would be understood that this action will be made even though conditions indicate a better action should be selected, until the necessary processes have been completed in order to implement BMP 5 (or something similar).

Culverts often pass under roadways and may necessitate road work, such as with the marsh at Cedar Beach. It may be that installation of properly sized culverts will require so much roadwork that planning will require several years. However, the culvert may fail and require immediate repair. In such an instance, replacement in kind may be assayed. If unmaintained, the culvert could clog and restrict tidal flow. This could lead to poor drainage from the marsh, increased mosquito breeding, vegetation changes, and further degradation of existing conditions.

None of the potential impacts associated with changes in hydrology will occur with interim action. However, neither will any of the benefits sketched in BMP 5. Here again, the action essentially preserves current conditions – even if they are suboptimal – until a better solution can be devised.

IMA 4. Stop-gap Ditch Plug Maintenance

Thin, three foot ditch plugs were installed in approximately a dozen locations in Suffolk County. Generally, a majority of these plugs have failed. They erode, or are undercut by muskrats. However, in some instances the ditch plugs, even if some have failed, appear to be meeting important goals for marsh restorations. For instance, the ditch plugged marshes at the William Floyd Estate still retain water, in some instances. Anecdotal surveys of bird prevalence, for example, suggest that these marshes attract more birds comprising a more diverse population structure than most marshes that are not plugged. In some instances, mosquito breeding appears to have diminished following ditch plugging.

For some of these ditch-plugged marshes, the continued failure of the plugs and/or more extensive mosquito breeding may signal a need to take some form of water management action in the marsh. If it is not possible to determine or conduct an optimal water management solution, then interim measures need to be taken. Where information exists that the ditch plugs appeared to be achieving the goals associated with the restoration project, the reconstruction of the plugs similar to their original construction may be a successful interim measure. Although three-foot ditch plugs are rarely identified as an optimal OMWM technique, these kinds of plugs would be re-installed as an interim measure until a more appropriate BMP can be installed. This would only be acceptable if these plugs are not intended to be permanent, but rather a strictly temporary action that appears to be justified in terms of past marsh responses to the original plugs.

At West Sayville on the South Shore, ditch plugging was done under the direction of Robert Parrish (USFWS) in 1998. The typical ditch plug was constructed with a small piece of plywood, about three feet long, placed in the ditch with marsh material placed behind it. A small fish reservoir was a common feature just behind the plug. Over time, the plugs became vegetated, and the plywood was no longer visible. Many of the plugs resulted in an increase in vegetation diversity, including *S. patens*, especially towards the uplands, and many large ponds actively used by fish. *Phragmites* in the upper marsh appear to be dying back where ponded water has been maintained. Because the marsh no longer drains at low tide, mudflats have become standing pools which have provided habitat for a diverse amount of birds. Historical patterns at other sites suggest that the majority of those ditch plugs are likely to fail relatively soon. By maintaining these plugs, existing vegetation, hydrology, and fish and wildlife habitat would be sustained.

Not maintaining these plugs may result in negative impacts to the marsh. If the plugs fail due to erosion, undermining by muskrats, or other causes, the hydrology of the marsh would change significantly. Prior to installing the ditch plugs, the ditches would drain at low tide. Therefore, by allowing these ditches to drain, marsh pools would dry and impact existing wildlife. Fish access to mosquito breeding sites would decrease and vegetation changes would shift to species that prefer drier conditions.

Although each marsh is different, there are indications that full ditch plugs may not be the best means of conducting water management under very low tidal ranges, such as are found at West Sayville. It may be that alternate water management strategies would be preferred for this site should restoration be reconsidered. Maintenance of the existing structures allows for current, well-received conditions at the site to be maintained until it is determined if reinforcing the existing plugs, or an entirely new strategy altogether, is warranted for the marsh.

7.6.3 Summary

The analysis of the BMPs and IMAs showed that it is possible, in the right setting, to employ these techniques to achieve reductions in mosquito populations, thereby reducing impacts from mosquito–borne disease and reducing pesticides usage, while also potentially achieving great environmental restoration ends. It is also clear that conducting these kinds of operations without regard for natural settings has the potential to not achieve mosquito control ends and to cause major environmental damage.

Suffolk County has outlined in the Wetlands Management Plan a series of management controls, including collaborative approaches to major projects and extensive oversight of its operations, to attempt to ensure that positive results are achieved by implementing these potentially environmentally beneficial actions. Oversight activities include the formation of a Steering Committee to oversee major projects and to establish a County-wide, overall marsh management policy, with the intent of subsuming this more mosquito management focused Wetlands Management Plan within a more ecologically-centered plan. This, and making use of the experience gained in neighboring jurisdictions, as was the case in the development of the Wertheim project, holds the promise that the County can achieve its ambitious goals.

The use of ditch maintenance as a means of conducting water management will be limited to approximately 50 acres of marsh in any one year. This restriction recognizes that other alternatives are available that have the potential to be as effective, if not more effective, in controlling mosquito breeding. The alternatives, as discussed above, also may avoid some potential impacts that have been associated with ditch maintenance, and to enhance other natural resource values, as well.

BMP 1 (natural reversion) seems to be the preferred option for approximately 4,000 acres of the County's salt marshes, at a minimum. These sites (specified below in Table 7-1) were identified in the Wetlands Management Plan as marshes that either do not have excessive mosquito breeding, lack affected populations in their immediate vicinity to be impacted by breeding, or are subject to regulations that prohibit water management altogether (or, perhaps, water management for the purposes of vector control).

Table 7-1. Non-Intervention Marshes (Marshes with no SCVC Mosquito Problems)

Town	**Marsh**
Babylon	Captree Island East Captree Island West Cedar and surrounding islands Eldar, Great and Helicopter Island & Bay Islands Seganus Thatch, Oak Island West Cedar Island Complex
Brookhaven	East Fire Island Flax Pond Great Gun Marsh Mt. Sinai Harbor Otis Pike Wilderness Area Ridge Island Stony Brook Harbor Wading River West Watch Hill
East Hampton	Gardiners Island Northwest Creek
Huntington	Crab Meadow Lloyd Neck, Caumsett State Park
Islip	Captree Island East of Robert Moses Causeway
Riverhead	Wading River
Shelter Island	Mashomack Forest Preserve
Smithtown	Nissequogue River Stony Brook Harbor
Southampton	Cowyard Beach to Goose Creek Hubbard Creek Jessup Neck Robins Island Sebonac Creek
Southold	None

Similarly, some 4,000 acres of salt marsh (in 43 distinct locations around the County) have been identified, by virtue of currently receiving aerial applications of larvicide on a regular basis, as sites that should be subject to progressive water management (Table 7-2). The BMPs described above clearly indicate that this is to be a targeted management process, in many ways very different from the indiscriminant grid ditching of marshes seventy years ago. Not all of these sites will require major projects to address the breeding that occurs there now, although it is likely that some will. The overall implementation of progressive water management by the County, and specific major projects, will be subjected to continuing scrutiny by the Screening Committee. This will allow concerned regulators, local governments, marsh managers, and other interested parties to review and guide the County's approaches to water management for mosquito control purposes. It is also likely that specific marshes, based on input from natural resource and marsh managers, will include design elements that extend beyond those needed to merely address a breeding area. This has been recognized in the discussion above, and is the basis for asserting that the implementation of progressive water management, especially the techniques that have the potential for the most impacts, can also potentially result in environmental improvements.

Table 7-2. Aerially-Larvicided Salt Marshes

Town	**Marsh**
Babylon	Captree Island East of Robert Moses Causeway Captree Island West Cedar Beach Gilgo Gilgo Island Helicopter Island Oak Beach/Sore Thumb Oak Island West Gilgo
Brookhaven	Beaverdam Creek Fireplace Neck/Manor of St. George Hedges (Abbotts) Creek Johns Neck Creek Lyman Marsh Mastic Beach Pattersquash Island Sayville Yacht Club Smith Point North Stillman Creek Wertheim NWR
East Hampton	Accabonac Harbor Napeague Harbor
Huntington	None

Town	**Marsh**
Islip	Captree Island East of Robert Moses Causeway Clam Pond Heckscher State Park/Quintuck Creek/Scully & Webster Estates/Scully Audubon/Islip Preserve Gardiner Estate/Gardiner Park Ludlows Creek/Benton Bay Namkee Creek Nature Conservancy Isbrandsen State TW/ Admiralty Island Quintuck Creek Pepperidge Hall State TW Pickman Remmer State TW/Idle Hour Seatuck NWR Timber Point State TW West Sayville/Indian Creek/ West Oak Recreation
Riverhead	Baiting Hollow Indian Island
Shelter Island	None
Smithtown	Sunken Meadow
Southampton	Iron Point Moneybogue Bay North Haven/Short Beach North Sea Harbor Shinnecock Bay, South Side/Meadow Lane/Westhampton Dunes Stokes-Poges/Jagger Lane
Southold	East of Pipes Cove/Pipes Neck Creek West of Pipes Cove/Kerwin Boulevard

Finally, some 9,000 acres of salt marshes do not clearly fall into the categories where management is either required or not required. These sites (Table 7-3) will need to be evaluated by the County (with review by other interested parties) to determine if mosquito control should be contemplated. If the site potentially might be subject to progressive water management, then it will be treated as the 43 sites in Table 7-2 will be—appropriate review and scrutiny by the Steering Committee and other reviewers.

Table 7-3. Marshes Needing Assessment

Town	**Marsh**
Babylon	None
Brookhaven	Bellport Bay State Tidal Wetlands Conscience Bay Cupsogue County Park/Swan Island Dunton Creek Forge River Harts Cove Havens Point Heils Creek Moriches Inlet Mud Creek Port Jefferson Harbor Radio Point Setauket Harbor Smiths Point Park Swan River Terrell River Tuthill Cove West Meadow Creek, Stony Brook William Floyd Estate
East Hampton	Alewife Pond and Cedar Point Fresh Pond Georgica Pond Lake Montauk Little Northwest Creek Montauk Point Oyster Pond Three Mile Harbor
Huntington	Asharoken, Southeastern End Duck Island Harbor North Cove Duck Island Northeast Side Duck Island West Side Eatons Neck, Winkle Point Huntington Harbor, West End Lloyd Neck, East Beach Lloyd Neck, South Shore Lloyd Neck, West End Morgan Estates Northport Harbor, Island and Yacht Club St. Johns Marsh, Cold Spring Harbor
Islip	Browns River State Tidal Wetlands Sexton Island
Riverhead	Browns Point Iron Pier Area Reeves and East Creeks South Jamesport Terry Creek-Meetinghouse Creek

Town	**Marsh**
Shelter Island	Cattail Pond Coecles Inlet Crab Creek Dering Harbor Smith Cove, South Ferry Town Beach West Neck Harbor
Smithtown	None
Southampton	Cold Spring Pond Cowyard Beach to Goose Creek Cupsogue County Park/Swan Island North Haven, South and East Sides Mecox Bay Peconic River Penniman Cove Penniman Creek Pine Neck Quantuck Bay Red Creek Pond Reeves Bay Sagaponack Lake Speonk River Squire Pond Stock Farm Taylor and Heady Creeks & Shinnecock Indian Reservation Westhampton Beach Wooley Pond
Southold	Brush Creek Cedar Beach Corey Creek Cutchogue Harbor, East Creek, Mud Creek, Haywater Cove, Broadwater Cove Cutchogue Harbor, Wickham Creek Dam Pond and Orient Causeway Deephole Creek Downs and West Creeks Goldsmith Inlet Park Goose Creek Gull Point and Sterling Creek Hashomomuck Pond Hippodrome Creek James Creek Jockey Creek, Town Creek Little Creek Long Beach Bay Mattituck Inlet and Creek Meadownw Beach Preserve Nassau Point Orient State Park Paradise Point Reydon Shores Richmond Creek

Map 7-1 (separate attachment) specifies the locations of these sites, by group.

The intent of the first three years of projects is to establish a track record for the County, in terms of technical competency with these projects, but also to demonstrate a willingness to work with landowners and other interested parties to develop projects that meet with needs and desires of all concerned with a particular marsh through a cooperative process. It seems likely that until an overall County wetlands management strategy is developed by the Screening Committee, major marsh restoration projects will be limited to Wertheim National Wildlife Refuge. Some of the projects undertaken in the first three years that use "no to little impact" or "minor impact" Best Management Practices may exceed size thresholds (set at 15 acres) and so require Screening Committee consideration, as well.

Jurisdictions such as Connecticut and the individual agencies in New Jersey that have implemented OMWM (using different techniques across different marshes and jurisdictions) have the common experience of reporting that well-designed projects appear to eliminate the need for larvicide applications. Connecticut claims that 20 year old projects still do not require any other mosquito control, and that maintenance needs are minimal to none (P. Capotosto, CDEP, personal communications, 2003, 2004; T. Candeletti, Ocean County (New Jersey) Mosquito Control Commission, personal communication, 2004). Thus, USFWS is willing to embrace progressive water management, especially as initial analyses of its own three year monitoring study of OMWM seem to indicate similar kinds of results. In addition, USFWS is excited about the potential of progressive water management to enable it to meet other natural resource goals, such as suppression of *Phragmites*, "naturalization" of marshes, and support for its overall mission to provide migratory bird habitat (S. Adamowicz, Region V, USFWS, personal communication, 2004; P. Martinkovic, LI Complex Director, USFWS, personal communications, 2004). In addition, due to the USFWS three year monitoring project, and other monitoring and research efforts on Refuge properties, there is a underlying set of environmental data to help meet NYSDEC pre-project monitoring requirements at these sites, which may make an important issue for other sites easier to address at the USFWS holdings. Ducks Unlimited, another important local participant in marsh management projects and OMWM demonstrations, also has a long-established relationship with USFWS.

Insofar as particulars regarding project design have not yet been determined, this document cannot provide site-specific environmental review of the potential initial projects. However, the projects will employ the BMP Manual, and so the analysis provided above (along with the provisions for future environmental review, discussed in Section 1) will hold, generically, for any initial projects conducted in the first three year interval of the Long-Term Plan.

7.7. Impacts of the Long-Term Plan: Part 5, Biocontrols

This section discusses impacts from the use of biocontrols. It begins by discussing impacts associated with the current program, and then describes the proposed changes to the current program associated with the Long-Term Plan, and the potential impacts of those changes.

7.7.1 Current Program

Biocontrols are currently limited in their use in the SCVC program. Mosquito fish, (*Gambusia spp.*) purchased from local supply houses, are the only biological control used (although biorational larvicides such as Bti and Bs are sometimes described as biocontrols).

There are some impacts associated with the stocking of *Gambusia* for mosquito control. These fish are not native to Suffolk County. The history of biological control contains a litany of situations where introduced species may have provided intended benefits, but the inadvertent impacts exceeded any possible gains (Howarth, 1991; Louda et al., 2003). Gambusia not only represents a potential invasive species that if released to streams or ponds could compete with local species (Courtney and Meffe, 1989), but it represents an important ecological threat even in isolated waters (per Goodsel and Kats, 1999). Many rare-threatened-endangered species in Suffolk County use vernal ponds or coastal plain ponds for habitat. Table 7-4 lists the species of concern in fresh water environments in Suffolk County (as compiled by the Natural Heritage Program). In vernal ponds, for example, the lack of year-round aquatic habitat limits the ability of predators to exploit the ecological niche (Diamond and Case, 1986). Many species, especially invertebrates and amphibians, therefore use these environments and their relatively safe harborage for breeding (Stewart and Springer-Rushia, 1998). Although recharge basins are not natural settings, those that do not retain water, if they drain slowly enough, can function ecologically as vernal pools; those that retain water sometimes mimic coastal plain pond environments because the level of the water often fluctuates due to stormwater inputs that then slowly recharge to the underlying sediments. Introducing fish into these environments can have devastating effects on the unprotected species used to a relatively predator-free environment (Knapp and Matthews, 2000).

Table 7-4. Natural Heritage Program R-T-E Species in Fresh Water Environments of Suffolk County

GROUP	SCIENTIFIC NAME	COMMON NAME	NY LISTING	HABITAT PREFERENCE
Dragonfly/Damselfly	*Enallagma minusculum*	Little Bluet	Threatened	F
Dragonfly/Damselfly	*Enallagma pictum*	Scarlet Bluet	Threatened	F
Dragonfly/Damselfly	*Enallagma recurvatum*	Pine Barrens Bluet	Threatened	F
Dragonfly/Damselfly	*Nehalennia integricollis*	Southern Sprite	Special Concern	F
Dragonfly/Damselfly	*Anax longipes*	Comet Darner	Unlisted	F
Dragonfly/Damselfly	*Enallagma laterale*	New England Bluet	Unlisted	F
Dragonfly/Damselfly	*Libellula needhami*	Needham's Skimmer	Unlisted	F
Dragonfly/Damselfly	*Ischnura ramburii*	Rambur's Forktail	Unlisted	F, S
Butterfly	*Callophrys hesseli*	Hessel's Hairstreak	Endangered	F
Amphibian	*Ambystoma tigrinum*	Tiger Salamander	Endangered	U, F
Amphibian	*Rana sphenocephala*	Southern Leopard Frog	Special Concern	F, U
Reptile	*Kinosternon subrubrum*	Eastern Mud Turtle	Endangered	F, S?
Bird	*Protonotaria citrea*	Prothonotary Warbler	Protected	F
Fish	*Enneacanthus obesus*	Banded Sunfish	Threatened	
Fish	*Etheostoma fusiforme*	Swamp Darter	Threatened	
Fish	*Aphredoderus sayanus*	Pirate Perch	Unlisted	
Vascular Plant	*Bartonia paniculata*	Screw-stem	Endangered	F
Vascular Plant	*Botrychium oneidense*	Blunt-lobe Grape Fern	Endangered	F
Vascular Plant	*Carex barrattii*	Barratt's Sedge	Endangered	F, U
Vascular Plant	*Carex bullata*	Button Sedge	Endangered	F
Vascular Plant	*Carex buxbaumii*	Brown Bog Sedge	Threatened	F
Vascular Plant	*Carex collinsii*	Collins' Sedge	Endangered	F
Vascular Plant	*Carex styloflexa*	Bent Sedge	Endangered	U, F
Vascular Plant	*Carex typhina*	Cat-tail Sedge	Threatened	U, F
Vascular Plant	*Carex venusta var. minor*	Graceful Sedge	Endangered	F, U
Vascular Plant	*Chamaecyparis thyoides*	Atlantic White Cedar	Rare	F
Vascular Plant	*Chasmanthium laxum*	Slender Spikegrass	Endangered	F
Vascular Plant	*Coreopsis rosea*	Rose Coreopsis	Rare	F
Vascular Plant	*Cyperus flavescens*	Yellow Flatsedge	Endangered	F
Vascular Plant	*Dichanthelium wrightianum*	Wright's Panic Grass	Endangered	F
Vascular Plant	*Eleocharis engelmannii*	Engelmann's Spikerush	Endangered	F
Vascular Plant	*Eleocharis equisetoides*	Knotted Spikerush	Threatened	S, F
Vascular Plant	*Eleocharis fallax*	Creeping Spikerush	Endangered	F, S
Vascular Plant	*Eleocharis quadrangulata*	Angled Spikerush	Endangered	F
Vascular Plant	*Eleocharis tenuis var.*	Slender Spikerush	Endangered	U, S, F?

GROUP	SCIENTIFIC NAME	COMMON NAME	NY LISTING	HABITAT PREFERENCE
	pseudoptera			
Vascular Plant	*Eleocharis tricostata*	Three-ribbed Spikerush	Endangered	F
Vascular Plant	*Eleocharis tuberculosa*	Long-tubercled Spikerush	Threatened	F
Vascular Plant	*Eupatorium leucolepis var. leucolepis*	White Boneset	Endangered	F, U
Vascular Plant	*Eupatorium rotundifolium var. ovatum*	Round-leaf Boneset	Endangered	F
Vascular Plant	*Gamochaeta purpurea*	Purple Everlasting	Endangered	U
Vascular Plant	*Gaylussacia dumosa var. bigeloviana*	Dwarf Huckleberry	Endangered	F, U
Vascular Plant	*Hottonia inflata*	Featherfoil	Threatened	F
Vascular Plant	*Hydrocotyle verticillata*	Whorled-pennywort	Endangered	F
Vascular Plant	*Hypericum adpressum*	Creeping St. John's-wort	Endangered	F
Vascular Plant	*Hypericum densiflorum*	Bushy St. John's-wort	Endangered	F
Vascular Plant	*Hypericum denticulatum*	Coppery St. John's-wort	Endangered	F
Vascular Plant	*Hypericum prolificum*	Shrubby St. John's-wort	Threatened	U, F
Vascular Plant	*Iris prismatica*	Slender Blue Flag	Threatened	U, F
Vascular Plant	*Juncus marginatus var. biflorus*	Large Grass-leaved Rush	Endangered	F
Vascular Plant	*Juncus scirpoides*	Scirpus-like Rush	Endangered	F
Vascular Plant	*Juncus subcaudatus*	Woods-rush	Endangered	F
Vascular Plant	*Lachnanthes caroliniana*	Carolina Redroot	Endangered	F
Vascular Plant	*Lemna perpusilla*	Minute Duckweed	Endangered	F
Vascular Plant	*Lilaeopsis chinensis*	Eastern Grasswort	Threatened	S
Vascular Plant	*Lipocarpha micrantha*	Dwarf Bulrush	Endangered	F, U
Vascular Plant	*Listera australis*	Southern Twayblade	Endangered	F
Vascular Plant	*Ludwigia sphaerocarpa*	Globe-fruited Ludwigia	Threatened	F
Vascular Plant	*Lycopodiella caroliniana var. caroliniana*	Carolina Clubmoss	Endangered	F
Vascular Plant	*Lycopus rubellus*	Gypsy-wort	Endangered	U
Vascular Plant	*Lysimachia hybrida*	Lance-leaved Loosestrife	Endangered	F, U
Vascular Plant	*Myriophyllum pinnatum*	Green Parrot's-feather	Endangered	F
Vascular Plant	*Oldenlandia uniflora*	Clustered Bluets	Endangered	F, U
Vascular Plant	*Platanthera ciliaris*	Orange Fringed Orchid	Endangered	U, F
Vascular Plant	*Platanthera cristata*	Crested Fringed Orchis	Endangered	U
Vascular Plant	*Polygala lutea*	Orange Milkwort	Endangered	F
Vascular Plant	*Polygonum careyi*	Carey's Smartweed	Threatened	F, U
Vascular Plant	*Polygonum hydropiperoides var. opelousanum*	Opelousa Smartweed	Threatened	F
Vascular Plant	*Polygonum setaceum var. interjectum*	Swamp Smartweed	Endangered	F, U
Vascular Plant	*Populus heterophylla*	Swamp Cottonwood	Threatened	F
Vascular Plant	*Potamogeton pulcher*	Spotted Pondweed	Threatened	F
Vascular Plant	*Proserpinaca pectinata*	Comb-leaved Mermaid-weed	Threatened	F

GROUP	SCIENTIFIC NAME	COMMON NAME	NY LISTING	HABITAT PREFERENCE
Vascular Plant	*Rhynchospora inundata*	Drowned Horned Rush	Threatened	F
Vascular Plant	*Rhynchospora nitens*	Short-beaked Bald-rush	Threatened	F
Vascular Plant	*Rhynchospora scirpoides*	Long-beaked Bald-rush	Rare	F
Vascular Plant	*Rotala ramosior*	Tooth-cup	Threatened	F, U
Vascular Plant	*Sagittaria teres*	Quill-leaf Arrowhead	Endangered	F
Vascular Plant	*Schizaea pusilla*	Curlygrass Fern	Endangered	F
Vascular Plant	*Sesuvium maritimum*	Sea Purslane	Endangered	F, U
Vascular Plant	*Sphenopholis pensylvanica*	Swamp Oats	Endangered	F
Vascular Plant	*Tipularia discolor*	Cranefly Orchid	Endangered	U, F
Vascular Plant	*Utricularia radiata*	Small Floating Bladderwort	Threatened	F
Vascular Plant	*Utricularia striata*	Fibrous Bladderwort	Threatened	F
Vascular Plant	*Viburnum nudum var. nudum*	Possum-haw	Endangered	F

F = Fresh Water
U = Upland
S = Salt Water

7.7.2 Long-Term Plan

The County is investigating whether fathead minnows (*Pimephales promelas)* can be used as effectively as *Gambusia.* It appears that they can, as this fish is tolerant of relatively poor water conditions, and also is said to be an effective consumer of mosquito larvae. One issue may be whether its preference for bottom waters will reduce its larval predation. If the basin is deep enough, there may be a habitat disconnection between where the potential predator prefers to be, and where the larvae are generally found. Although fathead minnows are not native to Suffolk County, history has shown they do not have the potential that *Gambusia* does as an invasive species. Fathead minnows would represent the same ecological threat *Gambusia* does in terms of disruption of predator-free environments, however.

If the minnows are introduced judiciously and appropriately, the impacts from the Long-Term Plan would appear to be less than those associated with current operations. It remains to be seen whether the minnows (or other potential replacements, such as pumpkinseeds) are as effective as mosquito fish at controlling mosquito larvae. Generally, introducing a predator into an environment is not as effective for pest control purposes as enhancing the environment to make it more amenable for a predator that already exploits the ecological niche. This is because the introduced predator, if it is successful at controlling the pest, will either die or must find alternate food sources. If it dies off, then it must be reintroduced if the pest reappears. If it is not to die off, finding alternate food sources generally means it must compete with a native species for the resource (although ecological cycles are not necessarily zero-sum situations, and "room" may be found for the predator). Therefore, stocking fish into fresh water environments is much more disruptive to the ecosystem than, for example, enhancing water quality in a salt marsh to allow *Fundulus* to exploit a greater area of the marsh, and so find different food sources.

The impacts of stocking fish will be minimized, it is hoped, through proposed new cooperative efforts between local natural resource experts and SCVC. The Wetlands Management Plan has called for the sharing of local knowledge regarding fresh water settings around the County, as many Town and other local experts have deep knowledge regarding certain specific local sites, and so can advise SCVC regarding where (and when) sensitive species can be found in these settings. Sharing this knowledge (with SCVC recording the information in its GIS data base) can ensure that SCVC does not act so as to cause impacts to these important species.

In addition to this proposed change regarding stocking of particular fresh water fish, the County is also interested in some other forms of biocontrol. In particular, predacious copepods may be useful, as they have been reported anecdotally to thrive in catch basins. New Jersey is experimenting with these organisms, and, if successful, SCVC could consider inoculating catch basins that retain water with copepods (in place of larvicides). One problem is that the inoculated copepods must reproduce to ensure effective control, which can take a period of time (and thus may allow some *Cx. pipiens* to grow to adulthood). Although a population lag for predators in response to the new availability of prey appears to be a biological necessity, the species of copepod being tested does reproduce quickly, and is very fecund (which is why it is being considered).

Biocontrols can therefore have some effective on mosquito populations, and therefore reduce the potential impact of mosquito-borne disease. They can, when effective, mean that larvicides do not need to be used, and so reduce the potential for impacts associated with pesticides. Biocontrols are an adjunct to water management.

Biocontrols have the potential for causing adverse environmental impacts, due to the potential for an introduced species such as *Gambusia* to reduce local and native biodiversity. Introducing predators into certain ecosystems may have devastating impacts on certain important species that require predator free zones in order to develop. The extent of the impact depends precisely on which environment the predator is introduced into. Some environments may be very robust, and suffer no ill effects; others may be irretrievably altered. Therefore, extreme care will need to be used in selecting locations for the use of predaceous fish.

7.8 Impacts of the Long-Term Plan: Part 6, Larval Control

7.8.1 Introduction

This section discusses the impacts of the use of larval controls. The Long-Term Plan will continue to use the same three biorational larvicides, *Bacillus thuringiensis var. israelensis* (Bti), *Bacillus sphaericus* (Bs), and methoprene, which are currently used to control larval mosquitoes. Therefore, although the proposed Long-Term Plan will include some changes to the current larvicide program, the discussion of impacts will begin by determining the impacts associated with the current program. The impact determination will be based on the quantitative risk assessment, literature studies, and field work conducted in association with the Long-Term Plan. The literature associated with potential impacts to human health and the environment from the pesticides considered through the Long-Term Plan process have been extensively reviewed prior to conducting this impact assessment (CA-IC, 2004; CA-SCDHS, 2005). In addition, impacts associated with application methodologies will also be discussed. Benefits associated with using these larvicides will also be reviewed, based on efficacy data collected elsewhere and also in Suffolk County. Differences between the impacts and benefits associated with the current program and those that might result from the Long-Term Plan will then be addressed.

7.8.2 Current Program

All larvicide applications under the current program are made on the basis of surveillance, where a need for the treatment was determined. Surveillance includes site visits by inspectors and routine monitoring of the nearly 2,000 breeding points in the County. No larval control efforts are made without supporting surveillance data.

The current program uses Bti, Bs, and methoprene as biorational larvicides to control mosquitoes prior to their developing to adults. These pesticides are considered to be biorational because they use biological processes and principles to achieve mosquito control.

Bs and Bti are natural spore-forming organisms. In the case of Bti, they do not replicate when applied into the environment as a pesticide, while Bs spores may reproduce following consumption by a mosquito larvae. Bti and Bs kill mosquito larvae following consumption, when enzymes in the mosquito gut activate toxins in the spores.

Methoprene is a chemical designed to mimic certain insect growth hormones. Methoprene applications ensure that the insects that use this particular hormone do not develop past a certain stage. Methoprene is absorbed by the insect (it is a contact insecticide, therefore), and then interferes with the receptor sites of the natural hormone within the larvae.

These larvicides are applied in long time-release formulations to catch basins and recharge basins. Catch basins and recharge basins receive solid forms of these pesticides, which then dissolve. Methoprene, when applied as a liquid over larger areas, uses a micro-encapsulation delivery, which is intended to result in constant release rates over approximately a one-week interval. Bti and Bs are often applied in association with some carrier like a corn cob fragment, as this keeps the pesticide floating where it will be consumed by the larvae (these formulations are not very effective if they sink to bottom sediments).

7.8.2.1 Quantitative Risk Assessment for *Bti*, *Bs*, and Methoprene

Much of the important background information for the risk assessment was presented in Section 4. In brief, application scenarios were developed in association with the County, and were intended to provide a range of reasonable applications that might be expected to occur in each of the four study areas. These application scenarios were based on past practices, and so will represent the current program well.

7.8.2.1.1 Introduction and Background

This risk assessment was conducted by Integral Consulting (Annapolis, MD) (Integral), acting as a subconsultant to CA. The text of the risk assessment is summarized in the Task 8 Task Report Summary (Cashin Associates, 2005b) and presented in full in Section III of that report (Cashin Associates, 2005c).

The analytic framework for the risk assessment was fashioned around the risk assessment paradigm developed initially by the National Academy of Sciences (NAS, 1983). In this context, risk assessment is the process of assigning magnitudes and probabilities to the adverse effects of human activities. This process involves identifying hazards, such as the release of a pesticide, and using measurement, testing, and mathematical or statistical models to quantify the relationship between the initiating event and the effects.

The NAS framework serves as the foundation for virtually all risk assessments conducted in the United States, including regulatory programs within USEPA and the FDA. It routinely is used to support the development of risk-based management strategies focused on reducing overall risks to human health and the environment and, as such, provides an appropriate analytic framework to assess risks potentially associated with pesticide use for vector control in Suffolk County.

The NAS paradigm divides risk assessment into four major steps:

1. hazard identification
2. dose-response assessment
3. exposure assessment
4. risk characterization (including an analysis of uncertainties).

This risk assessment has been conducted to address each of these components.

Hazard Identification

Hazard identification is the process of determining whether exposure to a stressor can cause an increase in the incidence of a health or ecological consequence. For this risk assessment, the stressors of concern are pesticides that are used for vector control.

For both the human health and ecological risk evaluations, the first step of the hazard identification was the development of a conceptual model that characterizes how a pesticide can be released into the environment, how it will behave once released, how it can reach human or ecological receptors, and what types of effects might be associated with exposure.

The conceptual model was developed from information about the planned pesticide use, the potentially affected populations (both human and ecological), and the potential exposures. It was used to focus the impact analysis on a defined set of stressors, receptors, and health and ecological endpoints.

Dose-Response Assessment

Dose-response assessment is the process of characterizing the relationship between exposure and the incidence of an adverse health or ecological effect in the exposed human or ecological population. It takes into account the toxic mechanisms by which a chemical can affect human or ecological receptors and the potency for causing toxic effects. It also considers how a toxic response changes as a function of exposure intensity, frequency, and duration, as well has how toxicity can vary by life-stage (e.g., children, pregnant women) or health status (e.g., immuno-compromised individuals).

For both the human health and ecological risks assessments, the output of the dose-response assessment was an identification of numerical criteria that were used in the risk assessment. To the extent possible, these criteria were derived from published guideline values recommended by governmental agencies, such as USEPA and the Agency for Toxic Substances and Disease Registry (ATSDR), or other expert public health or toxicological research groups (e.g., WHO, or the International Agency for the Research on Cancer [IARC]).

Exposure Assessment

Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of exposure to a stressor. In this risk evaluation, exposures were modeled by calculating chemical release, transport, degradation and transformation, along with the rate and magnitude of contact by humans and ecological receptors. Models developed by USEPA and other expert organizations were used.

Data from the literature and published guidance were used as the primary source of input to the exposure modeling. Data collected as part of early action projects initiated under the Literature Search and monitoring programs and Early Action Projects (see Section 6) were used to assess certainty in the model-predicted results.

Risk Characterization

Risk characterization is the process of estimating the incidence of a health or ecological effect under the various conditions of exposure described in the assessment. It is performed by combining the exposure and dose-response assessments. The uncertainties of the risk estimates are also fully explored in this step.

In this assessment, risks were characterized using the methods and approaches of USEPA. In addition, quantitative risk estimates using standard USEPA methodology were supplemented by a number of additional evaluations based on more detailed models or on health and ecological studies published in the peer-reviewed and technical literature. Data from study-area specific investigations (e.g., the Caged Fish and invertebrate field studies) conducted as part of Long-Term Plan activities were additionally used to assess potential impacts associated with vector control pesticide applications. This type of weight-of-evidence analysis generally adds strength to the conclusions that can be drawn from the risk analysis, and reduces the impact of uncertainties on the ability to make management decisions.

Data Sources and Information Relied Upon

This risk assessment relied importantly on data compilations and assessments conducted by other members of the CA consultant team. For example, the air modeling used as the starting point for the pesticide exposure assessment was conducted by RTP Environmental Associates Inc. (RTP). The human health toxicology review and compilation of toxicity criteria was conducted by SCDHS and CA. Information on land use, human populations, and ecology within the county was compiled jointly by CA and Cameron Engineering. Other information was provided directly by SCDHS, SCVC, and others retained by CA as consultants in this effort. None of this information has been independently verified by Integral, but has been used as reported by these different organizations. The information from these other groups and relied upon by Integral to conduct this risk assessment is largely presented elsewhere in this document, or has been compiled in the appendices associated with Cashin Associates (2005b).

In addition to these project-specific data sources, other data to support the risk assessment were derived from USEPA and other governmental agencies' guidance documents and reports and from literature published in peer-reviewed journals or other venues. Some of the data previously presented in the GEIS prepared on behalf of Westchester County (Westchester, 2001) was also used, but in most instances only if first independently verified by Integral. The specific information sources relied upon are referenced throughout this report and in the associated technical appendices.

7.8.2.1.2 Compounds Evaluated

Larvicide applications were evaluated as a management tool to control mosquito abundance in high-density mosquito areas. Applications were assumed to occur via hand or via a variety of delivery systems, including backpack blowers and sprayers, truck and aerial (helicopter) sprayers. Larvicides were assumed to be applied directly to mosquito breeding areas, including catch basins and wetlands. The larvicides evaluated were:

- *Bacillus thuringiensis israelensis (*Bti*).* Bti is a naturally occurring soil bacterium that produces toxins that are effective against mosquito and black fly larvae. Bti products include Vectobac and Teknar.
- *Bacillus sphaericus* (Bs). Bs is a naturally occurring bacterium found in soil and aquatic environments that produces toxins that are effective against mosquito larvae. Bs products include Vectolex.
- Methoprene. Methoprene is a biochemical larvicide that acts as an insect growth regulator, initially preventing mosquito larvae from maturing and ultimately causing mosquito mortality. Methoprene is the active ingredient in the larvicide product Altosid.

The application sites and scenarios have been previously discussed in Section 4.

7.8.2.1.3 Conceptual Model

Development of a conceptual model is essentially the first step in any risk assessment. The conceptual model is an organizing element designed to synthesize various pieces of information related to potential exposure and risks and identify the receptors, pathways, and endpoints that are to be the focus the subsequent risk evaluation.

As defined by USEPA (1998a) and others, the important factors critical to the development of a conceptual risk assessment model include information defining the characteristics of the:

(1) Stressor (in this case, a pesticide) as it enters and moves in the environment;

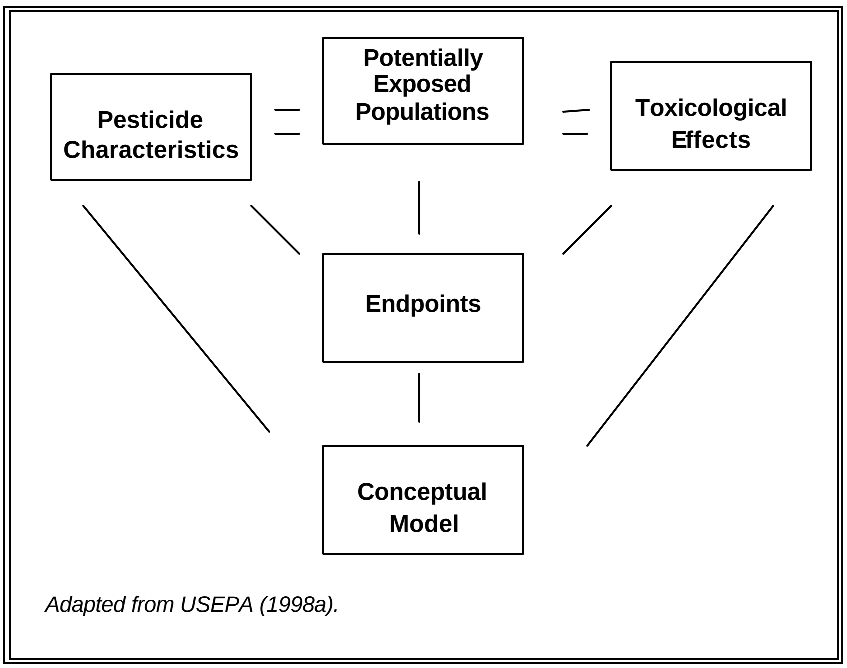
(2) Types of effects that could be associated with exposure to the stressor;

(3) Potentially exposed population that could contact (i.e., be exposed to) the stressor; and

(4) Endpoints that are most important to characterizing risks.

Figure 7-1 depicts the process used to develop the conceptual model for this risk assessment. The intent is to make an identification of the receptors and endpoints that will be the focus of the subsequent human health and ecological risk assessments.

Figure 7-1. Conceptual Model Development for the Risk Assessment



Pesticide Characteristics – Release and Fate in the Environment

The evaluation management plan outlines a series of management options that are predicated on direct release of pesticides into the environment. The amount of pesticides released, the frequency, timing, and location of their release, and their environmental fate and persistence once released are direct determinants of the potential for human or ecological exposures. This section summarizes key chemical-specific information important to defining potential pesticide exposures (see Table 7-5), and provides a conceptual overview of how pesticides might move and persist in the environment.

Table 7-5. Physical and Chemical Properties of Larvicides

	Parameter	Value	Units	Source	Notes
Methoprene					
	CAS No.	40596-69-8	--	CAS	--
	Molecular weight	310.48	--	HSDB	--
	Molecular formula	C19H34O3	--	HSDB	--
	Melting Point	--	^oC	--	--
	Solubility (in water)	1.4	ppm	HSDB	room temperature
	Henry's Law Constant (solubility)	6.90E-06	atm. M^3/mol	HSDB	--
	Vapor Pressure (in mPA)	--	mPA	--	--
	Vapor Pressure (mm Hg)	2.36E-05	Mm Hg	HSDB	@25^oC
Bacillus sphaericus (**Bs*****)***					
	CAS No.	143447-72-7	--	--	--
	Molecular weight	--	--	--	--
	Molecular formula	--	--	--	--
	Dissociation constant	--	negative log	--	--
	Solubility (in water)	--	ppm	--	--
	Henry's Law Constant (solubility)	--	atm. M^3/mol	--	--
	Vapor Pressure (in mPA)	--	mPA	--	--
	Vapor Pressure (mm Hg)	--	Mm Hg	--	--
Bacillus thuringiensis israelensis (**Bti*****)***					
	CAS No.	6803-87-11	--	--	--
	Molecular weight	--	--	--	--
	Molecular formula	--	--	--	--
	Dissociation constant	--	negative log	--	--
	Solubility (in water)	--	ppm	--	--
	Henry's Law Constant (solubility)	--	atm. M^3/mol	--	--
	Vapor Pressure (in mPA)	--	mPA	--	--
	Vapor Pressure (mm Hg)	--	Mm Hg	--	--
Notes					
-- = Not available or not applicable					
CAS = Chemical Abstract Service					
ARS PPDB = USDA's Agricultural Research Service Pesticide and Properties Database (USDA, 2005)					
Extoxnet = Extension Toxicology Network (1996a)					
HSDB = National Library of Medicine's Hazardous Substances Data Bank (NLM, 2005)					

Bti is a naturally occurring soil bacterium used as a microbial pesticide. Microbial pesticides are comprised of microscopic living organisms (e.g., bacteria, fungi, protozoa) or the toxins produced by these organisms. Bti is used to control the filter feeding stages of mosquito, black fly, midge, and fungus gnat larvae (Valent Biosciences Corp., undated; USEPA, 1998b; NCIPM, 2004a; Glare and O'Callaghan, 1998). Granular and liquid formulated products can be applied through ground or aerial application (Valent Biosciences Corp., undated). Bti is commonly registered under the trade names VectoBac and Teknar. It exerts its pesticidal activity through the production of endotoxins that are specifically toxic to black fly and mosquito larvae (CA-IC, 2004).

The environmental behavior of Bti and *Bacillus thuringiensis* (Bt) strains in general has been fairly well studied and is gauged primarily based on demonstrated efficacy in the field (USEPA, 1998b). In general, Bti is effective from one to seven days after application. UV light in the range of 300 to 400 nanometers (nm), falling within the wavelength range of sunlight, has been shown to inactivate both spores and endotoxins of Bt (Gelernter, 2001). Bti toxin can last for a few months in the soil and has an above-ground half-life of one to four days on plant surfaces. As a result, exposure to most above-ground non-target organisms is expected to be minimal (USEPA, 1998b). In aquatic environments, Bti has a tendency to bind to particulate matter in the water column, and in this form, is too large to be ingested by insect larvae (Gelernter, 2001). Thus, the efficacy of Bti may be limited in aquatic systems with a large amount of particulate matter (Yousten et al., 1992; Weinzierl et al., 1997).

Bti, as is the case with Bt strains in general, does not colonize or cycle (reproduce and persist to infect subsequent generations of pests) in the magnitude necessary to provide continuing control of target pests (Weinzierl et al., 1997). The bacteria may multiply in the infected host, but bacterial multiplication in the insect does not result in the production of abundant spores or endotoxins (Weinzierl et al., 1997; USEPA, 1998b). Once the target larvae die, few or no infective units are released into the environment (Weinzierl et al., 1997).

Bs, like Bti, is a naturally occurring bacterium used as a microbial pesticide. Bs is found naturally in soil and aquatic environments. Commercial formulations utilizing Bs (e.g., VectoLex) consist of living bacteria that produce spores (NCIPM, 2004b). Granules that contain the Bs are mixed with water and other substances, and then sprayed from the air or from the ground (Valent Biosciences Corp., undated).

Bs spores produce two delta-endotoxins that are toxic specifically to mosquito larvae upon ingestion (Valent Biosciences Corp., undated; Weinzierl et al., 1997; Lacey and Merritt, 2003; Mittal, 2003). Similar to the mode of action of Bti upon ingestion by mosquito larvae, Bs exerts toxicity through the release of the endotoxins, which result in the disruption of gut activity and ultimately lead to death.

As is the case with Bti, the environmental behavior of Bs has been fairly well studied and is gauged primarily on its efficacy in the field. The length of time that Bs remains effective against mosquitoes varies, depending primarily on the species and behavior of mosquito larvae, environmental conditions, and water quality (USEPA, 1999a; Lacey and Merritt, 2003; Gelernter, 2001). In general, Bs is effective for one to four weeks after application (USEPA, 1999a). As with Bti, UV light within the wavelength range of sunlight has been shown to inactivate both spores and endotoxins of Bs (Gelernter, 2001). Bs is less likely than Bti to adsorb to particulate matter and settle out of the water column. Therefore, it is considered to have generally higher efficacy against mosquito larvae in waters with higher degrees of particulates (Yousten et al., 1992; Weinzierl et al., 1997). As it occurs naturally, Bs does cycle and maintains itself in the environment. However the insecticidal formulations currently in use tend not to cycle in water to infect subsequent generations of mosquito larvae (Weinzierl et al., 1997).

Methoprene is a biochemical pesticide found in two formulations (methoprene and methoprene sustained release formula) and is registered under the Altosid trade name line.

Methoprene degrades rapidly in sunlight, both in water and on inert surfaces. Within three days of application, 90 percent of the applied material will degrade via photolysis and microbial metabolism. Without microbial metabolism, photolysis will degrade 80 percent in 13 days (USEPA, 1991a; USEPA, 2001a; USEPA, 2002a). Overall, methoprene has a half-life ranging from 30 hours to 14 days, depending on environmental conditions. Higher temperatures and salinity lead to higher degradation rates (Glare and O'Callaghan, 1999). The effects of methoprene last up to a week, but it reaches undetectable levels in ponds within 48 hours of application (Madder, 1980; Schaefer and Dupras, 1973). After four days, only one percent of the original application concentration will persist in the top two inches of soil. Because methoprene is tightly adsorbed to soil and is rapidly broken down, it is not likely to be transported to ground water (USEPA, 1991a; USEPA, 2001a; USEPA, 2002a). Methoprene sustained release formulation does not produce residual surface water concentrations greater than those produced with the application of a liquid formulation (Westchester, 2001). No degradation products have been identified as more toxic than parent methoprene.

All of the target pesticides are proposed for direct release into the environment and thereby have the potential to reach human or ecological receptors. The likelihood, magnitude, and duration of any potential exposure are dependent to a large degree on how the compound is released, where it is released and how it behaves once it is released.

Larvicides are applied as liquid or solid formulations directly to aquatic environments used as breeding grounds by adult mosquitoes. Once released into the aquatic environment, each of the target larvicides can remain in the water column in its biologically available and toxic form (spores for Bti and Bs; dissolved phase for methoprene). Some portion of the larvicide, however, will sorb to suspended material or bed sediment, which essentially reduces its overall availability and toxicity to biological organisms. As noted above, this is an important fate characteristic of Bti and, to a slightly lesser extent, of Bs. Methoprene, present whether in the water column or sorbed to sediments, is degraded by photolysis and microbial action, which results in a further decrease in its biologically available concentrations over time. There is no indication that any of these target larvicides accumulate in the food web.

Overall, the collective fate data suggest that these larvicides will dissipate relatively rapidly from the treated environment. However, under management scenarios in which the target larvicides are applied repeatedly during the mosquito season (e.g., up to 20 times per year in Mastic-Shirley), aquatic environments would experience multiple, short-term (pulsed) exposures to peak maximum concentrations. No cumulative build-up or residues are likely.

Toxicological Effects of Target Pesticides

When present at sufficiently high concentrations, the target pesticides can potentially cause a variety of toxic effects in both humans and wildlife. A detailed review of the toxicology of these compounds is presented separately in CA-SCDHS (2005) and CA-IC (2004). A brief summary is presented below to support development of the conceptual model.

Bti exerts its toxicity through the production of endotoxins that are specifically toxic to black fly and mosquito larvae (CA-IC, 2004). It is produced commercially in large fermentation tanks, and as bacteria live and multiply in the right conditions, each cell produces an asexual reproductive spore and a crystalline structure containing protein toxins called endotoxins (specifically delta-endotoxins) (Weinzierl et al., 1997; Mittal, 2003). Commercial products containing Bti may consist of the endotoxins and spores (USEPA, 2000a), or just the endotoxins (NCIPM, 2004a). The endotoxins associated with the Bti spore must be ingested by larvae before they act as poisons (and are therefore referred to as "stomach" poisons). After ingesting Bti, enzyme activity and alkaline conditions in the larvae's gut break down the crystalline structures, and activate the endotoxins (Mittal, 2003; Weinzierl et al., 1997). Once the endotoxins are activated, they rapidly bind to the cells lining the midgut membrane and create pores in the membrane, upsetting the gut's ion balance. This results in paralysis of the gut, thus interfering with normal digestion and feeding (Brown, 1998; Weinzierl et al., 1997; Lacey and Merritt, 2003; Dale and Hulsman, 1990).

Bti's selectivity in terms of its ability to target the larvae of certain insect species, particularly mosquito and black fly larvae, is attributable to the types of endotoxins it produces and the particular physiological conditions required to activate the endotoxins (CA-IC, 2004). There is some evidence of Bti effects to non-target aquatic dipterans that include midges (Chironomidae), biting midges (Ceratopogodinae), and dixid midges (Dixidae), which are commonly associated with mosquitoes within the aquatic environment. These organisms are taxonomically similar to mosquitoes and black flies and can possess the gut pH and enzymes necessary to activate the endotoxins. Adverse effects to these groups, however, have only been noted at dosages 10 to 1,000 times greater than the application rate specified for mosquito control (FCCMC, 1998).

Because of its selectivity, Bti generally is not considered a risk to non-target organisms, and USEPA has concluded that that Bti does not pose significant adverse risks to non-target organisms or the environment, especially since rates higher than those used for vector control are needed to produce any adverse effects (USEPA, 1998b). Recent literature confirms Bti's limited overall toxicity to wildlife (Brown et al., 2002; Russell et al., 2003; Lacey and Merritt, 2003).

Bti does not appear to be toxic to humans. USEPA (1998b) reported that there was no evidence that it is pathogenic to mammalian species, not that it caused adverse effects on body weight gain or tissue or organ damage upon necropsy of treated animals (CA-SCDHS, 2005). WHO (1999) has concluded that Bt products are unlikely to pose a health risk to humans

Bs is generally not considered a risk for non-target organisms. The commercially available form of Bs, VectoLex, has been extensively tested and is considered non-toxic to non-target organisms (Westchester, 2001; NYSDEC, 1996b). USEPA concluded that Bs does not pose any significant risk to non-target organisms or the environment (USEPA, 2000a).

There is no evidence that Bs is infectious, pathogenic or toxic to humans (CA-SCDHS, 2005; McClintock et al., 1995). Further, USEPA (1998c) concluded that residues of Bs on food would not be expected to result in harm, considering the low mammalian toxicity of Bs and its ubiquitous occurrence naturally.

Methoprene disrupts insect maturation and reproduction by mimicking the activity of natural juvenile insect hormone (CA-IC, 2004). At sufficiently high concentrations, it also has been shown to be toxic to fresh water invertebrates and fish, estuarine and marine invertebrates, and amphibians (USEPA, 2002). Fresh water invertebrates are especially sensitive to methoprene, with a lowest observable adverse effect concentration (LOAEC) of 51 ppb reported (USEPA, 2002). Overall, the potential for aquatic toxicity is mitigated by the rapid degradation of methoprene in surface water (Extoxnet, 1996a).

Methoprene is generally considered to be slightly toxic to non-toxic to terrestrial wildlife. The oral median lethal dosage (LD_{50}) for rats is greater than 10,000 mg/kg (USEPA, 2002). Methoprene is considered slightly toxic to birds (Extoxnet, 1996a). In mallards, an acute oral LD_{50} of greater than 2,000 mg/kg in the diet was determined. Dietary no observed effect concentrations (NOECs) (based on reproductive endpoints) range from three ppm for mallard ducks to 30 ppm for bobwhite quail (USEPA, 2002). Some data also suggest that methoprene may be toxic to bees. Schulz et al. (2002) reported that methoprene affected honeybee foraging activity.

Overall, methoprene is not expected to be toxic to humans. Its insecticidal properties are due to its action as an insect juvenile hormone analogue, which is a mechanism that is selective to insects (WHO, 1984). Methoprene has been shown to produce liver and kidney toxicity in laboratory animals under certain exposure conditions (CA-SCDHS, 2005). Methoprene does not appear to be carcinogenic or to cause endocrine or reproductive effects.

Potentially Exposed Populations

The human and ecological populations potentially exposed to pesticides released during vector control are dependent upon the land use and natural characteristics of the area. Section 4 has provided a description of this information for each of the study areas considered in this evaluation. This information is now used to identify potentially exposed populations that are representative of the current study areas, as well as of the county as a whole.

All of the study areas support mixed human uses. Predominant land use within the study areas include:

- Residential;
- Commercial;
- Industrial;
- Parks and other recreational areas; and
- Undeveloped open space.

Overall, these land uses generally are representative of the County as a whole, and are considered here to represent the suite of potential land uses potentially associated with vector control activities in the future. The principal receptor populations in the study areas include residents, workers, and recreational users (e.g., boaters, anglers, swimmers).

None of the study areas support large agricultural operations, which do occur in some of the less developed portions of the County. Because of their lower population density, agricultural areas are not typically the focus of vector control operations, and therefore this land use is not considered in this assessment. Small-scale community gardens and backyard gardens do occur in the study areas, and are included in residential and open space land use categories as noted. Calculated health risks potentially occurring in community and back-yard gardeners will overestimate any exposures that could occur in people consuming agricultural commodities from regional farms, if vector control pesticides were ever to be used in these areas in the future. This is because the general public would only obtain a small proportion of its total produce from any one regional farm, whereas a potentially much higher proportion could be obtained from backyard or local community gardens.

A diversity of natural habitats occurs within and around the study areas. This diverse mixture is due to a natural diversity of habitats within Suffolk County coupled, in part, with land preservation programs that set aside especially important ecological habitats and communities. For example, the Wertheim National Wildlife Refuge occurs in the northeast section of the Mastic-Shirley study area. FINS abuts portions of the Mastic-Shirley and Davis Park study areas. The Great South Bay-East, which comprises half of the largest protected coastal bay in New York State, also falls within the buffer area of both the Mastic-Shirley and Davis Park study areas. The Otis G. Pike Wilderness area, which is the only federally designated wilderness area in New York State, is approximately one-half mile east of the Davis Park study area. The Peconic River, which is the largest groundwater fed river in New York State, occurs adjacent to the Manorville study area and supports a unique assemblage of coastal plain kettle ponds. Table 7-6 summarizes the diversity of habitats that occur across all study area.

Table 7-6. Ecological Habitats Associated with Study Areas

Ecological Risk Assessment Habitat Settings		**Study Areas**			
		Davis Park	**Mastic-Shirley**	**Dix Hills**	**Manorville**
Aquatic Settings					
Fresh water					
Lentic	pond, kettle pond, vernal/ephemeral pool, depression	X	X	X	X
	lake				X
Lotic	stream		X		X
	river				X
Marine-Estuarine					
Coastal waters	embayment	X	X		
	tidal creek		X		
Transitional Settings					
Inland Wetlands					
Riverine	wetlands along river/stream channels				X
Lacustrine	wetlands along lakes/reservoirs				X
Palustrine	wet meadows, bogs, bottomlands, red maple swamps		X	X	X
Coastal Wetlands					
High marsh, salt meadow		X	X		
Intertidal marshes		X	X		
Mudflats/Beach/Dune					
Intertidal bars, mudflats		X	X		
Dune, fore-dune, scrub pine		X			
Terrestrial Settings					
Upland					
Upland forest& woodlands			X	X	X
Upland old fields, meadows, agricultural lands				X	X
Landscaped/residential			X	X	X
Ruderal field				X	

Within these diverse habitats, an even greater diversity of potential ecological receptor populations exists. For the purposes of this risk assessment, potential receptors were broadly grouped by taxa to address the diversity of ecological receptors potentially present. These groupings were based on study-area specific knowledge of the habitats and representative species, as well as consideration of the types of data that are available to support the subsequent ecological risk assessment.

For terrestrial habitats, including and transitional (wetland) environments, the potential receptor groups are:

- Mammals (e.g., deer, raccoon, mice);
- Birds (e.g., insectivorous songbirds, waterfowl, and other water-associated birds);
- Reptiles (e.g., turtles, snakes);
- Non-target insects (e.g., honeybees, butterflies, dragonflies); and
- Plants.

For aquatic habitats, including transitional (wetland) environments in fresh water, marine, and estuarine settings, receptor groups are:

- Fish (e.g., bluegill, rainbow trout, mummichog);
- Amphibians (e.g., frogs);
- Crustaceans (e.g., crayfish, crabs, lobster);
- Aquatic insects and larvae (e.g., benthic organisms, stoneflies);
- Mollusks (e.g., snails, clams, oysters); and
- Aquatic plants (e.g., algae).

Within these potentially exposed populations, there are subgroups of individuals or species that might be especially sensitive or susceptible to effects from exposure to the target pesticides. This could be due to a variety of factors including a unique development life stage (e.g., fetus, child) or physiological condition (e.g., elderly, immuno-compromised or pregnant individual), a unique behavior (e.g., soil ingestion in children), or overall population status (e.g., endangered species).

In human health assessment, risks to such sensitive members of the population are commonly addressed by making adjustments to the assumptions that are used to characterize exposures in potentially susceptible population subgroups, and by making adjustments to the numeric dose-response criteria that are used to assess toxicity. USEPA typically attempts to protect individuals who represent high-end exposures (typically around the 90th percentile and above) and those who have some underlying biological sensitivity (USEPA, 2004a). In so doing, USEPA aims to protect sensitive members of the population, as well as the rest of the population. USEPA's approach for addressing risks to sensitive members of the population was adopted for this risk assessment. As a consequence, this risk assessment has addressed potential risks to members of potentially sensitive subpopulations, as well as the populations as a whole.

In ecological risk assessment, endangered and threatened species typically are regarded as especially sensitive receptors, given the already vulnerable status to their population. For these reasons, risks to endangered and threatened species are typically evaluated along with risks to other non-endangered or non-threatened wildlife.

The study areas potentially support a number of threatened and endangered (T&E) species. Table 7-7 identifies the T&E animal species that could occur in the study areas and that were included in this ecological risk assessment. In addition, the County also provides habitats for a number of T&E plants, and these too were considered in this assessment. Section 4 provides a more complete description of the T&E species potentially occurring in the study areas.

Table 7-7. Threatened and Endangered Animal Species Potentially Occurring in or Near Study Areas

GROUP	SCIENTIFIC NAME	COMMON NAME	NY LISTING	HABITAT
Dragonfly/Damselfly				
	Enallagma minusculum	Little Bluet	Threatened	Ponds
	Enallagma pictum	Scarlet Bluet	Threatened	Ponds
	Enallagma recurvatum	Pine Barrens Bluet	Threatened	Ponds
Butterfly				
	Callophrys hesseli	Hessel's Hairstreak	Endangered	Cedar swamps, ponds
	Speyeria idalia	Regal Fritillary	Endangered	Grassland
	Callophrys irus	Frosted Elfin	Threatened	Pitch pine-scrub oak barrens
Amphibian				
	Ambystoma tigrinum	Tiger Salamander	Endangered	Pine barren ponds
Reptile				
	Kinosternon subrubrum	Eastern Mud Turtle	Endangered	Ditches, creeks
Bird				
	Laterallus jamaicensis	Black Rail	Endangered	Salt marshes along south shore of Long Island.
	Asio flammeus	Short-eared Owl	Endangered	Low vegetation areas.
	Charadrius melodus	Piping Plover	Endangered	Coastal or inland beaches.
	Sterna dougallii	Roseate Tern	Endangered	Coastal or inland beaches.
	Sterna antillarum	Least Tern	Threatened	Coastal or inland beaches.
	Sterna hirundo	Common Tern	Threatened	Coasts, marshes.
	Bartramia longicauda	Upland Sandpiper	Threatened	Open fields, pastures, golf courses, etc.
	Circus cyaneus	Northern Harrier	Threatened	Marshes, meadows, bogs.
	Podilymbus podiceps	Pied-billed Grebe	Threatened	Marshes, ponds, lakes.
Fish				
	Enneacanthus obesus	Banded Sunfish	Threatened	Sluggish waters; headwater tributaries.
	Etheostoma fusiforme	Swamp Darter	Threatened	Sluggish waters.

Endpoints

Endpoints in a risk assessment context are defined as the receptor and its particular attributes that are to be protected (USEPA, 2005c).

Typically, in human health risk assessment, the endpoint of interest is protection of individual members of the population from the adverse effects of chemicals (USEPA, 2004a). The adverse effects of the chemicals are most commonly classified into two broad types of health effects: cancer effects and non-cancer effects. Non-cancer health effects encompass a variety of health endpoints, such as neurological, reproductive, immunological, endocrine, and developmental effects.

In contrast to human health assessment, the endpoint of interest in ecological risk assessment is protection of ecological populations (collections of individual organisms belonging to a given species), communities (collections of populations), or ecosystems (USEPA, 1998a). The attributes to be protected are typically related in someway to the long-term stability or sustainability of the population, community, or ecosystem. These include attributes such as abundance and age-structure within populations, and species diversity and abundance within communities. Effects on individual organisms are generally not relevant unless they are sufficient in magnitude to adversely impact long-term stability or sustainability at higher levels of ecological organization.

The term assessment endpoint is commonly used to refer to the endpoints of focus in ecological risk assessment. In this risk assessment, the term assessment endpoint was used to define the endpoints of interest for both the human health and ecological assessments.

The assessment endpoint for the human health assessment was protection of individual members of the population, including sensitive subpopulations, from the adverse health effects from exposure to adulticides and an associated synergist.

The assessment endpoints for the ecological risk assessment were:

- Maintenance of abundance of fish, invertebrate, and amphibian populations that utilize habitats potentially affected by application of target pesticides.

- Maintenance of abundance of terrestrial wildlife populations, including mammals, birds, and reptiles that utilize habitats potentially affected by application of target pesticides.
- Maintenance of abundance of non-target terrestrial insect populations that utilize habitats potentially affected by application of target pesticides.
- Maintenance of diversity and biomass within the vegetative communities in areas potentially affected by application of target pesticides.
- Maintenance of abundance of the populations of endangered or threatened species that utilize habitats potentially affected by application of target pesticides.

7.8.2.1.4 Human Health Risk Assessment

Protection of human populations from potential exposures to larvicides was not evaluated because, as apparent from the earlier review, these compounds have been shown to be relatively non-toxic to humans. Further, because larvicides are applied directly to water and rapidly degrade and/or become biologically unavailable, there is very little potential for human exposure to these compounds. The NAS paradigm for risk assessment cannot determine risks when neither a hazard assessment can be completed, nor a pathway for exposure has been established (NAS, 1983), as is the case with human health and these larvicides.

Table 7-8. Summary of the Human Health Risk Assessment for Larvicides

Agents Considered	Most Critical Endpoint Considered	Pathway Considered Potential Risk	Locations with Potential Risk	Conclusion in Risk Assessment	Comments	Role in Management Plan
Methoprene	NA	Not expected to be human health risk due to limited exposure	No locations were of concern	Not expected to be human health risk	Not quantitatively evaluated because exposure expected to be minimal	Preferred larvicide based on effectiveness for all larvae Stages, used in combination with Bti
Bti	NA	Not expected to be human health risk due to limited exposure	No locations were of concern	Not expected to be human health risk	Not quantitatively evaluated because exposure expected to be minimal	Preferred larvicide effective for Stage I, II & III larvae
Bs	NA	Not expected to be human health risk due to limited exposure	No locations were of concern	Not expected to be human health risk	Not quantitatively evaluated because exposure expected to be minimal	Preferred larvicide effective for Stage I, II & III larvae. Especially good in polluted, freshwater habitats used by Culex spp.

7.8.2.1.5 Ecological Risk Assessment

The ecological risk assessment (ERA) was conducted to evaluate the potential for ecological impacts from the proposed uses of the target pesticides. The overall focus was an assessment of the potential for the target pesticides to adversely affect the structure, function, or interactions of ecological populations and communities residing within Suffolk County in and near areas receiving vector control pesticide applications.

The ERA was conducted using methods and protocols developed by USEPA (1993b, 1997b, 1998a, 1999c, 2001b) along with accepted methodologies presented in the literature (e.g., Pastorok et al., 1996; Sample and Suter, 1994; Sample et al., 1996; Sample et al., 1997; Suter et al., 2000).

The ecological risk assessment additionally draws upon a wealth of information collected during empirical studies conducted in support of the collective impact assessment being conducted under the Long-Term Plan process. This includes Suffolk County-specific field data and laboratory data collected on the environmental fate and effects of control agents (see Section 6). Additional information on the long-term impacts of mosquito control agent use on aquatic and terrestrial communities in other parts of the country was critically reviewed and incorporated as appropriate in the ecological risk assessment. This includes the long-term studies conducted in Minnesota by the Minnesota Metropolitan Mosquito Control District (principally reported by Read, 2001; Balcer et al., 1999; Hershey et al., 1998; Niemi et al., 1999) and by Charbonneau et al. (1994) as well as studies conducted in Florida (e.g., as reported by Emmel and Tucker, 1991) and in Suffolk County (as reported by Barnes, 2005).

The conceptual model developed jointly for human and ecological receptors was used as the starting foundation of the ecological risk assessment. That model showed that target pesticides could be released and move in the environment and potentially reach a variety of ecological receptors in terrestrial and aquatic habitats in Suffolk County. From this broad conceptualization, additional analyses were conducted to quantify the potential exposures in these receptor groups, define toxic response as a function of exposure, and characterize risk as a function of exposure and toxicity.

Assessment Approach

The particular methods used to evaluate ecological risk are dependent on the type of habitat and receptor of interest, but broadly followed a similar framework consisting of receptor identification, exposure assessment, dose-response assessment, and risk characterization (including uncertainty analysis).

<u>Receptor Characterization</u>

Ecological risk assessments were conducted for each of the four study areas identified in the evaluation management plan. Within each study area, predominant habitats across aquatic, transitional, and terrestrial habitat settings were first identified based on field observations made by Integral ecologists visiting each study area and using information on study area-specific ecology compiled by CA (with Cameron Engineering), presented in Section 4. These habitat groupings were used to frame the assessment and the receptors that would be evaluated for aquatic, terrestrial, and transitional settings. A total of 17 predominant habitats across aquatic, transitional and terrestrial habitat settings were identified and evaluated in this ERA, as discussed above. These 17 habitats are the predominant ecological habitats present throughout the County, and as such are good surrogates for evaluating potential ecological risks not only in each study area, but also in other areas of the county that might receive target pesticide applications in the future.

Once the habitats were identified, the potential receptors (species) that could be exposed in each were selected for evaluation. Potential receptors were identified first based on identification of each major taxa potentially inhabiting an area (e.g., reptiles, amphibians, birds, mammal, fish, aquatic invertebrates, terrestrial insects, plants), and then by species within taxa, based on general knowledge of species-specific habitat preferences. The potential presence of endangered and threatened species was considered when selecting receptors or receptor groups for the evaluation.

Exposure Assessment

The pathways and routes of exposure were identified for each habitat-receptor combination. Exposure was quantified by estimating target pesticide fate and transport, and receptor-specific intakes.

Information on application method, timing, and frequency of control agent defined in the Evaluation Management Plan was utilized to define the introduction of target pesticides into the environment, and subsequently, to support predictive modeling on environmental behavior, fate and transport. The ecological risk assessment initially relied upon quantitative air modeling performed by RTP (Section 4) to determine resultant control agent deposition rates and air concentrations following various application scenarios.

Both the use information and modeling were subsequently incorporated into comprehensive environmental fate and transport modeling to predict environmental concentrations of control agents over time in both aquatic and terrestrial settings. Degradation rates in the soil, sediments, and surface waters via abiotic (e.g., photolysis, hydrolysis, and redox reactions) and biotic processes (e.g., aerobic and anaerobic metabolism) were assumed to follow first order kinetics (consistent with Lyman et al. [1982], Howard et al. [1991], and others).

Wildlife exposure methods developed by USEPA (1993b, 1997b, 1999c) and others (e.g., Suter, 1993; Sample and Suter, 1994; Sample et al., 1997; Hoerger and Kenaga, 1972; Fletcher et al., 1994) were used to calculate exposures to wildlife species (e.g., mammals, birds). Estimated surface water concentrations were used to assess aquatic life exposures. All surface water exposure concentrations were calculated to be the freely dissolved fraction in water column, as this is the fraction that is most bioavailable to water column aquatic life (USEPA [2004b] and others).

<u>Dose Response Assessment</u>

Quantitative dose-response criteria were developed for specific receptors using published toxicological compilations and databases (e.g. USEPA's ECOTOX Database, Extension Toxicology Network [Extoxnet], National Library of Medicine's Hazardous Substances Data Bank [HSDB], various RED documents published under USEPA's FIFRA pesticide registration program) or otherwise published in the open literature. A complete summary of the sources used to compile ecotoxicological information serving as the basis for developing quantitative criteria is presented in CA-IC (2004). Most typically, the available toxicological data for ecological receptors is based on responses in individual organisms, whereas the focus of ERAs is most commonly on potential impacts on higher levels of ecological organization (e.g., populations and communities), as is the case in this ERA. To support extrapolation of individual-level based endpoints to population or higher ecological effects, a common approach in ecological risk assessment is to select toxicological data derived from studies that examined growth, reproduction, or survival, as these endpoints are most directly relevant to assessment of population-level impacts. This was the approach adopted in this ERA.

In selecting ecotoxicological data for use in the risk assessment, a number of additional screening criteria were employed:

- Preference was given to dose-response data for technical material or active ingredient data versus formulated products.
- Preference was given to studies employing species common in New York, although data for species that inhabited areas outside of New York was used if no data were available for New York-state species within a given taxa.

- Aquatic toxicity data for marine/estuarine species was summarized separate from that for fresh water species.
- If multiple data points were available for a given species and the data regarded to be of sufficiently high quality, then the average was used.
- For acute data, preference was given to 96 hr LC_{50} values, if available, rather than less conservative 24 or 48-hr values.
- Preference was given to toxicological levels that were reported for measured levels, as opposed to levels reported as “greater than” values.
- A variety of additional data quality considerations were considered based on adherence to standardized toxicological testing and reporting protocols to as described by Durda and Preziosi (2000).

Acute criteria were based on median lethal concentration (LC_{50}) values or median effective concentrations (EC_{50}). Chronic criteria were typically based on measured or estimated no-observable-adverse-effect concentrations or levels (NOAECs or NOAELs). The selected value was referred to as the toxicity reference value (TRV). Separate TRVs were evaluated for each receptor group.

Risk Characterization

Risks for all receptors were evaluated initially by comparing estimated exposures to selected toxicity criteria. This approach is called the Hazard Quotient (HQ) approach and computationally, is simply the ratio of estimated exposure concentration (EEC) or dose (EED) to the TRV:

$$HQ = \frac{EEC \text{ or } EED}{TRV}$$

HQs were calculated for each target pesticide product assuming that each was used exclusively during a given spray season.

The HQ approach is truly a screening-level assessment approach appropriate for determining which chemicals or pathways do not pose a risk. HQs that are less than one indicate that ecological risks are unlikely. HQs greater than one indicate that there may be concern for potential ecological effects under the conditions of exposure evaluated (USEPA, 1998a). Because the exposure and toxicity data used to support HQ calculations are based on responses in individual organisms, rather than ecological populations or communities (which are the focus of this assessment), they cannot be used to definitively characterize potential ecological risk.

In this ERA, receptors for which calculated HQs were less than one were assumed not to be at risk from exposure to the target pesticides, and were not evaluated either. If the calculated HQs exceeded one, additional evaluations were conducted.

The ecological risk evaluations were conducted at several levels:

1) The potential ecological consequences of the calculated risks were explored and placed into perspective in the context of the assessment endpoints identified for the ERA. If that evaluation suggested that the calculated risks were not sufficiently large or certain to represent a true ecological risk, or if no additional data were available to support refined risk estimates, no further evaluation was conducted.

2) If a potential risk was still deemed possible, a more refined analysis of pesticide fate and transport was conducted to better capture potential persistence and transport in the environment, as well as any key uncertainties in the assessment.

3) This was supplemented by an ecological community-level evaluation.

4) Uncertainties in the evaluation were more fully explored quantitatively.

Approaches 3 and 4 were not implemented for all chemicals or receptors.

Terrestrial Wildlife Risk Evaluation

Because larvicides are applied directly to water and because significant off-target drift is not expected, larvicide risks to terrestrial wildlife are anticipated to be negligible, and were not evaluated in this assessment.

Terrestrial Non-target Insect Risk Evaluation

Because larvicides are applied directly to water and because significant off-target drift was not found for aerial applications, and was not expected for hand-held applications, larvicide risks to terrestrial non-target insects are anticipated to be negligible.

Aquatic Life Risk Evaluation

Potential ecological risks were evaluated for aquatic life species present within fresh water and marine/estuarine surface waters of Suffolk County. Aquatic life could be potentially exposed to the primary control agents following application. The assessment endpoint was identified as maintenance of abundance of fish, invertebrate, and amphibian populations that utilize aquatic habitats potentially impacted by application of primary list control agents.

Two levels of analyses were conducted to evaluate potential risks to aquatic life:

- Level 1 – worst case aquatic life exposures and risk;
- Level 2 – refined evaluation of aquatic life exposures and risk;

Level 1: Worst-case Aquatic Life Exposure and Risk

Under the first level of assessment, simplistic and conservative modeling was used to provide upper-bound estimates of potential surface water concentrations and aquatic life risks associated with larvicides in each of the four study areas.

A variety of application scenarios were evaluated, including aerial (i.e., helicopter) and hand applications (inclusive of backpack sprayers and hand application of larvicides formulated as granules, pellets and briquets).

A total of five generic scenarios were evaluated for each study area:

- potential maximum and average indirect deposition to an open water body (e.g., pond);
- potential maximum and average indirect deposition to a shallow wetland;
- average deposition and resultant runoff from impervious surfaces into small open water body;
- maximum label rate-based hand application of larvicides into a small open water body; and,
- potential maximum indirect deposition into a small open water body and a shallow wetland and subsequent food chain exposures to raccoon, sandpiper and belted kingfisher.

The study area-specific modeled deposition rates provided by RTP (2005) were used to characterize indirect deposition of primary list control agents into surface waters. In the case of the evaluation of runoff, the modeled deposition rates were used to characterize potential deposition to impervious surfaces.

At this first conservative and worst-case level, no degradation, and only some degree of partitioning to sediments within a water body, were assumed. Nearly all of given control agent introduced into a water body was assumed to be fully dissolved, bioavailable, and present at a steady-state concentration. This modeling resulted in the prediction of instantaneous surface water concentrations for generic water bodies that were subsequently used in the characterization of worst-case aquatic life risks.

ERA Appendix E (presented in Cashin Associates, 2005c) presents complete and detailed technical documentation on the theoretical and numerical approaches used to model potential surface water concentrations and concomitant aquatic life risks predicted for open surface waters, shallow wetlands, runoff from impervious surfaces, and hand application of larvicides. ERA Appendix F (Cashin Associates, 2005c) presents this information for evaluation of potential bioaccumulation and food-chain exposure and risks.

Modeling of an open surface water body following aerial or truck application was performed using a standard pond setting. Under this setting, a pond is assumed to be 10,000 m^2 in area and two meters deep. This standard pond setting is equivalent to the default farm pond utilized by the USEPA Office of Pesticide Programs (OPP) to perform pesticide risk assessments for aquatic settings. The actual dimensions of the farm pond are based upon USDA Soil Conservation Service (SCS) specifications (USDA, 1982).

The pond is assumed to be absent of bed sediment and suspended sediment (hence, no partitioning is assumed), and is assumed to have no inflow or outflow. Although this standard pond was designed by USEPA to predict conservative pesticide concentrations in a small pond, it has also been shown to be a good predictor of upper-level pesticide concentrations in other small water bodies, including upland streams (Effland et al., 1999).

Surface water concentrations were calculated as a function of the study area-specific deposition rate (in g/m^2) as provided by RTP modeling and the area of the pond, the resultant total mass applied, and the volume of the pond. Deposition rates were adjusted to account for the peak deposition following multiple applications as they occur in each study area. The highest relative concentrations (i.e., peak concentrations) predicted for each control agent while accounting for exponential decay (as described in detail in ERA Appendix B [Cashin Associates, 2005c]) and repeated applications are calculated. Adjusting deposition rates by simply multiplying them by the maximum relative concentration scaling factors ensures that the peak concentration over the course of the application season is incorporated in the instantaneous surface water modeling. Both maximum average and average deposition rates were evaluated in this manner.

Open surface waters are present in each of the four study areas, and were modeled accordingly. Resultant concentrations were considered representative of concentrations in either fresh water or marine/estuarine settings.

Risks are calculated using the HQ method whereby predicted surface water concentrations were compared to acute TRVs for the most sensitive aquatic life species for both fresh water and marine/estuarine settings.

The results of the Level 1 assessment for a generic open water body found HQs for all larvicides to be less than one.

Modeling of surface water present in a shallow wetland following aerial or truck application was performed using the USEPA Interim Rice Model as described in USEPA (2004c, 2005a). The USEPA Environmental Fate and Effects Division (EFED) recently used this model for evaluations of both malathion and PBO under mosquito abatement application scenarios (USEPA, 2004f; USEPA, 2005a). The model represents a four inch (10 cm) deep water body that has an area of 10,000 m^2, similar to the wetlands described on the labels of most of the control agents. According to USEPA, it can be used to predict a conservative estimate of surface water concentration in a shallow wetland, shallow lake, or estuarine area receiving mosquito abatement application.

The Interim Rice Model incorporates the total mass of control agent entering a shallow wetland and accounts for partitioning between the water and sediment according to a linear K_d partitioning model. Total control agent mass potentially entering a shallow wetland was calculated based upon the study area-specific maximum average and average deposition rates modeled by RTP. The Interim Rice Model algorithm does not account for potential partitioning to suspended sediment in the water column, and thus it may result in an overestimation of the bioavailable fraction of a given control agent. The model also does not explicitly account for degradation over time.

Shallow wetlands are present in each of the four study areas, and were modeled accordingly. Resultant concentrations were considered representative of instantaneous concentrations in either fresh water or marine/estuarine settings.

Predicted maximum and average instantaneous surface water concentrations were compared to acute TRVs for the most sensitive aquatic life species for fresh water and marine/estuarine settings. Acute risks were expressed as hazard quotients.

The results of the Level 1 analysis for a shallow wetland showed HQs for all larvicides were below one.

An evaluation of runoff from impervious surfaces during a rain event occurring after the application of control agents was conducted. Potential aquatic life exposures and risks were evaluated assuming the runoff discharges to a small water body. The evaluation focused on runoff for larvicides following application by helicopter. Truck and backpack spray application of larvicides to water bodies are not anticipated to result in significant off-target depositions within terrestrial settings.

For the purposes of this evaluation, a small watershed within a densely populated residential area was evaluated. Of the four study areas, the modeled area was considered most representative of Mastic-Shirley.

The modeling approach used to evaluate runoff was based upon a simple mass balance fugacity approximation technique following Mackay (1991). Chemical equilibrium within a small watershed comprised of impervious surfaces (i.e., concrete, asphalt) and soil was modeled. Chemical equilibrium throughout an area of runoff was estimated by incorporating the chemical-specific soil sorption coefficient, (K_{oc}), along with the fraction of organic carbon (F_{om}) present in a variety of media (i.e., asphalt, concrete, soil) assumed to be present within the modeled area. Average deposition rates modeled by RTP for each of the control agents and the area of the application swath was used to calculate an average mass of chemical loaded (*M*) relative to the volume of all components of the modeled area.

This modeled area was assumed to consist of 75 percent impervious surfaces and 25 percent pervious surfaces, and is used to characterize and upper-end runoff scenario. Study area-specific average deposition rates were used to simulate an application scenario within each study area. Runoff from a rain event of 0.5 inches was evaluated. Runoff was assumed to flow directly into a small open surface water body, and a resultant control agent surface water concentration was predicted.

Average instantaneous surface water concentrations in a small water body receiving runoff from impervious surfaces were then compared to acute TRVs for the most sensitive aquatic life species for fresh water and marine/estuarine settings. Resultant acute risks are expressed as hazard quotients.

The results of the Level 1 analysis to address runoff from impervious surfaces found HQs less than one for all larvicides.

Modeling of an open surface water body following hand application of larvicides was performed using a shallow water body setting and the general approach described above. For this evaluation, a one meter deep water body was used to represent a shallow water body, such as a ditch or retention pond, where hand application of larvicides might occur.

Larvicides applied by hand or hand-generated methods in granule, pellet, briquette and dunk formulations were evaluated. These include methoprene (Altosid pellets, Altosid 30 day briquets, Altosid XR briquets), Bti (Vectobac G, Mosquito Dunks), and Bs (VectoLex CG). For methoprene, surface water concentrations were based upon the highest measured concentrations reported during a rate of release study for a 30 day briquette formulation by SandozAgro, Inc. (1994). For the remaining larvicides, maximum label-specified application rates, as presented on the product labels, were used to predict resultant surface water concentrations.

Instantaneous surface water concentrations in a small water body following repeated applications of larvicides at maximum label application rates were compared to acute TRVs for the most sensitive aquatic life species among fresh water and marine/estuarine species settings. Acute risks were expressed as hazard quotients.

The results of this Level 1 assessment of hand application of found that HQs were all less than one for all larvicides.

An aquatic food chain evaluation was performed based upon upper-bound and conservative estimates of food chain exposure conditions. Exposures and risks are evaluated for methoprene. Bti and Bs do not demonstrate a potential to bioaccumulate significantly in aquatic prey items such as fish and benthic invertebrates, and are therefore not addressed in this evaluation.

Food chain exposures were evaluated for three mid- to upper-trophic level consumers:

- raccoon
- sandpiper
- belted kingfisher

Potential dietary exposures were evaluated for each consumer preying upon either aquatic invertebrates, fish or both prey items obtained from either open surface waters or shallow wetlands within each of the four study areas. Information on dietary preferences and methods for calculating dietary uptake for these three receptors are based upon USEPA (1993a).

Uptake into aquatic prey was calculated based upon literature-reported bioconcentration factors (BCFs) under assumed steady state conditions (i.e., no environmental degradation, depuration, or metabolism occurs). The assumption that instantaneous worst-case surface water concentrations and steady state conditions exist are highly conservative, and in fact, implausible given the limited persistence and rapid metabolism of the majority the primary list agents. As described in detail in CA-IC (2004), none of the control agents are anticipated to bioaccumulate in aquatic environments to any great extent given their limited aquatic persistence and ability to be readily metabolized by most animals.

Dietary concentration for each consumer was compared to TRVs for avian and mammalian wildlife. TRVs were based upon the lowest available acute dietary LD_{50}s or LC_{50}s for common laboratory animals used in feeding studies. For the selection of TRVs, preference was given to toxicity tests based on the shortest duration under the assumption that concentrations in dietary items are predicted at time zero (i.e., instantaneous concentrations in prey items).

Based upon this evaluation, predicted HQs for raccoon, sandpiper and belted kingfisher are below one for methoprene.

Level 2 – Refined Evaluation of Aquatic Life Exposure and Risk

Under the second level of assessment, refined surface water modeling and aquatic life risk characterization were performed to evaluate potential aquatic life risks associated with larvicide applications.

ERA Appendix E (Cashin Associates, 2005c) presents complete and detailed technical documentation on the theoretical and numerical approaches used to perform refined modeling of potential surface water concentrations and concomitant aquatic life risks water body types present in each of the study areas.

Each of the control agents possesses physiochemical characteristics which indicate that they have a moderate to very high propensity to sorb to bed sediments and suspended sediments in aquatic environments. Fundamental toxicological principles dictate that the portion of a chemical that is actually dissolved as opposed to that which is sorbed to suspended sediment or bottom sediment has the greatest bioavailability, and is considered to be primarily responsible for aquatic toxicity. Further, as described in detail in ERA Appendix B (Cashin Associates, 2005c), each of the control agents also demonstrate limited persistence in aquatic environments, indicating that degradation over time is an important factor when modeling surface water concentrations used for characterizing aquatic life risks. The objective of this refined modeling, therefore, is to determine actual dissolved (i.e., bioavailable) concentrations of control agents during ecologically relevant exposure durations in surface water bodies.

For the refined modeling, study area-specific water body types were incorporated and included both fresh water and marine/estuarine settings. By using study-area specific water body types, a more complete characterization of potential aquatic risks could be evaluated for each individual study area.

In total, five water body types were evaluated:

- ponds;
- lakes (inclusive of reservoirs);

- streams (inclusive of rivers);
- wetlands; and
- embayments.

These water body types were considered characteristic of the predominant water body settings present in Suffolk County and were used as surrogates to represent all water body settings.

For the purposes of modeling surface water concentrations, the most critical physical dimension of a water body is its depth. This is because dilution following application (resulting in a modeled deposition rate) is calculated as a function of depth. The assumed depths of the five water body types used in the refined modeling were as follows:

- ponds – two meters
- lakes – three meters
- streams – one meter
- wetlands – 0.1 meters
- embayments – three meters

Water body types present within the targeted application area (i.e., the study area proper), as well as relevant water body types in the quarter mile buffer areas around each study area were included (Table 7-9). By doing so, risks could be characterized and considered inclusive of potentially sensitive water body types located in buffer areas, contiguous with buffer areas, or immediately adjacent to buffer areas. This is particularly relevant in the case of Davis Park, which is bounded by Great South Bay and FINS, and in the case of Mastic-Shirley, which is located near Wertheim NWR.

Table 7-9. Summary of the Study Area-specific Water Body Types Evaluated.

Dix Hills				
Pond in Target + Runoff	Wetland in Target + Runoff			
Davis Park				
Pond in Target + Runoff	Wetland in Buffer Drift + Runoff	Embayment in Buffer Drift + Runoff		
Manorville				
Pond In Target + Runoff	Wetland in Target + Runoff	Lake in Target + Runoff	Stream in Target + Runoff	
Mastic-Shirley				
Pond in Target + Runoff	Wetland in Target + Runoff	Embayment in Buffer Drift + Runoff	Stream in Buffer Drift + Runoff	Stream in Target + Runoff

As was the case under the first level of evaluation, study area-specific deposition rates modeled by RTP were used to characterize indirect deposition into water bodies present in each of the study areas. For this refined level of evaluation, RTP's modeled deposition rates for buffer areas were included for the evaluation of water bodies within or near each study area's buffer area.

All water bodies, whether located within the target or buffer, were assumed to receive runoff. Under short-term exposure conditions, runoff (expressed as a deposition rate) from impervious surfaces, as described above, was incorporated. In the case of longer-term exposures, runoff overland into water bodies was modeled based upon USEPA's EXAMS-PRZM exposure simulation model (EXPRESS) (USEPA, 2005d). Chemical-specific inputs as provided in ERA Appendix A (Cashin Associates, 2005c), and the application rate, timing and frequency of control agent use, as specified under the evaluation management plan, were used as inputs in the modeling.

The "standard agricultural field-farm pond" scenario used by USEPA for all aquatic exposure assessments conducted under pesticide registration was used in this evaluation. This standard pond scenario assumes that ten centimeters of rain fall on a treated, 10 hectare agricultural field, causing control agent runoff into a one hectare body of water of 20,000 cubic meters volume, two meters deep. In this evaluation, the agricultural field was assumed to consist of turf. Peak instantaneous concentrations predicted by EXPRESS in the surface water of the pond were back-calculated to derive an equivalent runoff deposition rate. By doing so, a cumulative deposition rate, accounting for both control agent application and for runoff, could be added and incorporated into the refined surface water modeling.

In order to provide refined estimates of dissolved concentrations of control agents, a series of sequential algorithms was employed to account for partitioning between the dissolved phase water, suspended solids, and benthic sediment. The resultant dissolved phase concentration in the water column is used to derive exposure concentrations used in the characterization of aquatic life risks. The dissolved water column concentrations were also considered to be representative of potential sediment pore water concentrations, and were subsequently used in the characterization of risks to benthic organisms. Some uncertainty remains with respect to potential direct toxicity posed by actual sediment pore water concentrations and indirect toxicity posed by that fraction of a control agent sorbed to sediments (e.g., ingestion of sediment by benthos and resultant gastric extraction of control agents). In certain instances benthic risks based on dissolved water column concentrations could underestimate benthic risks based on direct (i.e., pore water) and indirect (i.e., sediment ingestion/gastric extraction) sediment toxicity. This could particularly be the case for those control agents with higher affinities to bind to sediments and those with greater persistence in sediments. However, assessing benthic risks associated with direct and indirect sediment toxicity presents a number of additional uncertainties (e.g., variability and uncertainty in organic carbon and dissolved organic carbon, establishing chief route of exposure). Some uncertainties could be addressed using mechanistic modeling, though such assessments would most likely benefit from empirical toxicity studies.

The algorithms are based upon equilibrium partitioning theory and are driven by the partitioning potential of control agents in sediment/water systems. The algorithms are largely based upon dissolved surface water concentration algorithms presented by USEPA (1999d, 1999e), modified to take into account cumulative mass loading of control agents into surface water bodies via deposition from application and deposition from runoff. The algorithms explicitly address chemical partitioning between water, sediment, and total suspended solids (TSS) in a water body.

Refined estimates of acute and chronic risks were evaluated for larvicides. Risks were calculated for the following receptor groups:

Fresh water

- fish
- amphibians
- crustaceans
- mollusks
- aquatic insects/larvae
- aquatic plants

Marine/estuarine

- fish
- crustaceans
- mollusks
- aquatic insects/larvae
- aquatic plants

For the purposes of evaluating acute risks, 48 hour average concentrations were derived. For chronic risks, 14 day average concentrations were derived to evaluate risk to aquatic invertebrates and amphibians, and 90 day average concentrations were derived to evaluate fish.

Risks are characterized under the hazard quotient approach by comparing the refined estimated surface water concentrations to acute (i.e., LC_{50}s or EC_{50}s) and chronic (i.e., NOECs) TRVs for each of the receptor groups under fresh water and marine/estuarine conditions.

A complete summary of acute risks is presented in Table 7-10. No risk exceeds a HQ of one for the larvicides.

A complete summary of chronic risks presented below in Table 7-11. None of the larvicides had a HQ greater than 1.

Table 7-10. Summary of Refined Acute Aquatic Life risks (HQs>1 denoted in blue shading)

Chemical	Freshwater Aquatic Life Receptors	Marine/Estuarine Aquatic Life Receptors	Davis Park - HQs$_{acute}$			Dix Hills - HQs$_{acute}$		Manorville - HQs $_{acute}$				Mastic Shirley$_{Aerial}$ - HQs$_{acute}$								Mastic Shirley$_{Truck}$ - HQs$_{acute}$							
			Aquatic Setting																								
			FW	M/ES		FW		FW				FW				M/ES				FW				M/ES			
			Freshwater Pond/Depression in Target + Runoff	Coastal Wetland/Marsh in Buffer - Drift + Runoff	Coastal Embayment in Buffer - Drift + Runoff	Freshwater Pond/Depression in Target + Runoff	Freshwater Wetland in Target + Runoff	Freshwater Pond/Depression in Target + Runoff	Freshwater Wetland in Target + Runoff	Freshwater Lake in Target + Runoff	Freshwater Stream in Target + Runoff	Freshwater Pond/Depression in Target + Runoff	Freshwater Wetland in Target + Runoff	Freshwater Stream in Buffer - Drift + Runoff	Freshwater Stream in Target + Runoff	Coastal Wetland/Marsh in Target + Runoff	Coastal Embayment in Buffer - Drift + Runoff	Tidal Stream in Buffer - Drift + Runoff	Tidal Stream in Target + Runoff	Freshwater Pond/Depression in Target + Runoff	Freshwater Wetland in Target + Runoff	Freshwater Stream in Buffer - Drift + Runoff	Freshwater Stream in Target + Runoff	Coastal Wetland/Marsh in Target + Runoff	Coastal Embayment in Buffer - Drift + Runoff	Tidal Stream in Buffer - Drift + Runoff	Tidal Stream in Target + Runoff
Methoprene																											
	Fish	Fish	NC	NC	NC	2E-06	3E-06	2E-06	3E-06	2E-06	3E-06	3E-06	2E-05	3E-06	4E-06	3E-06	3E-07	5E-07	7E-07	2E-06	3E-06	NC	2E-06	5E-07	NC	NC	4E-07
	Amphibians	Crustaceans	NC	NC	NC	4E-05	6E-05	5E-05	7E-05	5E-05	5E-05	7E-05	4E-04	6E-05	9E-05	4E-03	3E-04	6E-04	8E-04	4E-05	6E-05	NC	5E-05	6E-04	NC	NC	4E-04
	Crustaceans	Mollusks	NC	NC	NC	2E-03	3E-03	2E-03	3E-03	2E-03	2E-03	3E-03	2E-02	3E-03	4E-03	2E-03	1E-04	2E-04	4E-04	2E-03	3E-03	NC	2E-03	2E-04	NC	NC	2E-04
	Mollusks	Aquatic insects/larvae	NC	NC	NC	4E-06	6E-06	4E-06	6E-06	4E-06	5E-06	6E-06	4E-05	6E-06	8E-06	1E-03	1E-04	2E-04	3E-04	4E-06	6E-06	NC	4E-06	2E-04	NC	NC	2E-04
	Aquatic insects/larvae	Aquatic plants	NC	NC	NC	1E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	1E-03	2E-04	3E-04	NC	NC	NC	NC	1E-04	2E-04	NC	2E-04	NC	NC	NC	NC
	Aquatic plants		NC			NC	NC	NC	NC	NC	NC	NC	NC	NC	NC					NC	NC	NC	NC				
Bti																											
	Fish	Fish	NC	NC	NC	4E-10	5E-10	4E-10	5E-10	4E-10	4E-10	4E-10	7E-10	2E-10	5E-10	7E-10	2E-10	2E-10	5E-10	4E-10	5E-10	NC	4E-10	5E-10	NC	NC	4E-10
	Amphibians	Crustaceans	NC	NC	NC	4E-10	5E-10	4E-10	5E-10	4E-10	4E-10	4E-10	7E-10	2E-10	5E-10	5E-08	1E-08	2E-08	4E-08	4E-10	5E-10	NC	4E-10	4E-08	NC	NC	3E-08
	Crustaceans	Mollusks	NC	NC	NC	3E-08	4E-08	3E-08	4E-08	3E-08	3E-08	3E-08	5E-08	2E-08	4E-08	5E-08	1E-08	2E-08	4E-08	3E-08	4E-08	NC	3E-08	4E-08	NC	NC	3E-08
	Mollusks	Aquatic insects/larvae	NC	NC	NC	3E-08	4E-08	3E-08	4E-08	3E-08	3E-08	3E-08	5E-08	2E-08	4E-08	5E-08	1E-08	1E-08	3E-08	3E-08	4E-08	NC	3E-08	4E-08	NC	NC	3E-08
	Aquatic insects/larvae	Aquatic plants	NC	NC	NC	3E-08	4E-08	3E-08	4E-08	3E-08	3E-08	3E-08	5E-08	1E-08	3E-08	NC	NC	NC	NC	3E-08	4E-08	NC	3E-08	NC	NC	NC	NC
	Aquatic plants		NC			NC	NC	NC	NC	NC	NC	NC	NC	NC	NC					NC	NC	NC	NC				

Acute hazard quotient of 1 is exceeded
Freshwater setting
Marine/estuarine setting
See Tables E-30 through E-36 for a complete presentation of surface water exposure concentrations, aquatic Life TRVs, and estimated acute aquatic life hazard quotients.

Table 7-11. Summary of Refined Chronic Aquatic Life Risks

			Davis Park - HQs$_{acute}$			Dix Hills - HQs$_{acute}$		Manorville - HQs$_{acute}$				Mastic Shirley$_{Aerial}$ - HQs$_{acute}$								Mastic Shirley$_{Truck}$ - HQs$_{acute}$							
			Aquatic Setting																								
			FW	M/ES		FW		FW				FW				M/ES				FW				M/ES			
Chemical	Freshwater Aquatic Life Receptors	Marine/Estuarine Aquatic Life Receptors	Freshwater Pond/Depression in Target + Runoff	Coastal Wetland/Marsh in Buffer - Drift + Runoff	Coastal Embayment in Buffer - Drift + Runoff	Freshwater Pond/Depression in Target + Runoff	Freshwater Wetland in Target + Runoff	Freshwater Pond/Depression in Target + Runoff	Freshwater Wetland in Target + Runoff	Freshwater Lake in Target + Runoff	Freshwater Stream in Target + Runoff	Freshwater Pond/Depression in Target + Runoff	Freshwater Wetland in Target + Runoff	Freshwater Stream in Buffer - Drift + Runoff	Freshwater Stream in Target + Runoff	Coastal Wetland/Marsh in Target + Runoff	Coastal Embayment in Buffer - Drift + Runoff	Tidal Stream in Buffer - Drift + Runoff	Tidal Stream in Target + Runoff	Freshwater Pond/Depression in Target + Runoff	Freshwater Wetland in Target + Runoff	Freshwater Stream in Buffer - Drift + Runoff	Freshwater Stream in Target + Runoff	Coastal Wetland/Marsh in Target + Runoff	Coastal Embayment in Buffer - Drift + Runoff	Tidal Stream in Buffer - Drift + Runoff	Tidal Stream in Target + Runoff
Methoprene																											
	Fish	Fish	NC	NC	NC	2E-06	3E-06	2E-06	3E-06	2E-06	3E-06	3E-06	2E-05	3E-06	4E-06	3E-06	3E-07	5E-07	7E-07	2E-06	3E-06	NC	2E-06	5E-07	NC	NC	4E-07
	Amphibians	Crustaceans	NC	NC	NC	4E-05	6E-05	5E-05	7E-05	5E-05	5E-05	7E-05	4E-04	6E-05	9E-05	4E-03	3E-04	6E-04	8E-04	4E-05	6E-05	NC	5E-05	6E-04	NC	NC	4E-04
	Crustaceans	Mollusks	NC	NC	NC	2E-03	3E-03	2E-03	3E-03	2E-03	2E-03	3E-03	2E-02	3E-03	4E-03	2E-03	1E-04	2E-04	4E-04	2E-03	3E-03	NC	2E-03	2E-04	NC	NC	2E-04
	Mollusks	Aquatic insects/larvae	NC	NC	NC	4E-06	6E-06	4E-06	6E-06	4E-06	5E-06	6E-06	4E-05	6E-06	8E-06	1E-03	1E-04	2E-04	3E-04	4E-06	6E-06	NC	4E-06	2E-04	NC	NC	2E-04
	Aquatic insects/larvae	Aquatic plants	NC	NC	NC	1E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	1E-03	2E-04	3E-04	NC	NC	NC	NC	1E-04	2E-04	NC	2E-04	NC	NC	NC	NC
	Aquatic plants		NC			NC	NC	NC	NC	NC	NC	NC	NC	NC	NC					NC	NC	NC	NC				
Bti																											
	Fish	Fish	NC	NC	NC	4E-10	5E-10	4E-10	5E-10	4E-10	4E-10	4E-10	7E-10	2E-10	5E-10	7E-10	2E-10	2E-10	5E-10	4E-10	5E-10	NC	4E-10	5E-10	NC	NC	4E-10
	Amphibians	Crustaceans	NC	NC	NC	4E-10	5E-10	4E-10	5E-10	4E-10	4E-10	4E-10	7E-10	2E-10	5E-10	5E-08	1E-08	2E-08	4E-08	4E-10	5E-10	NC	4E-10	4E-08	NC	NC	3E-08
	Crustaceans	Mollusks	NC	NC	NC	3E-08	4E-08	3E-08	4E-08	3E-08	3E-08	3E-08	5E-08	2E-08	4E-08	5E-08	1E-08	2E-08	4E-08	3E-08	4E-08	NC	3E-08	4E-08	NC	NC	3E-08
	Mollusks	Aquatic insects/larvae	NC	NC	NC	3E-08	4E-08	3E-08	4E-08	3E-08	3E-08	3E-08	5E-08	2E-08	4E-08	5E-08	1E-08	1E-08	3E-08	3E-08	4E-08	NC	3E-08	4E-08	NC	NC	3E-08
	Aquatic insects/larvae	Aquatic plants	NC	NC	NC	3E-08	4E-08	3E-08	4E-08	3E-08	3E-08	3E-08	5E-08	1E-08	3E-08	NC	NC	NC	NC	3E-08	4E-08	NC	3E-08	NC	NC	NC	NC
	Aquatic plants		NC			NC	NC	NC	NC	NC	NC	NC	NC	NC	NC					NC	NC	NC	NC				

Acute hazard quotient of 1 is exceeded
Freshwater setting
Marine/estuarine setting

Table 7-12. Summary of Ecological Risk Assessment for Larvicides

Agents Considered	Terrestrial Birds, Mammals, Reptiles	Terrestrial Insects	Aquatic Life	Comments	Conclusion in Risk Assessment	Role in Management Plan
Methoprene	No risk*	Not expected to be terrestrial risk due to limited exposure	No risk*	Terrestrial risks not quantitatively evaluated because exposure expected to be minimal	No ecological risks*	Preferred larvicide based on effectiveness for all larvae Stages, used in combination with Bti
Bti	No risk*	Not expected to be terrestrial risk due to limited exposure	No risk*	Terrestrial risks not quantitatively evaluated because exposure expected to be minimal	No ecological risks*	Preferred larvicide effective for Stage I, II & III larvae
Bs	No risk*	Not expected to be terrestrial risk due to limited exposure	No risk*	Terrestrial risks not quantitatively evaluated because exposure expected to be minimal	No ecological risks*	Preferred larvicide effective for Stage I, II & III larvae. Especially good in polluted, freshwater habitats used by Culex spp.

* That is, predicted exposures were below levels of concern established by USEPA and/or others and so do not indicate that there is an increased risk of unacceptable ecological impacts from use of the pesticides under the conditions evaluated in this assessment

The risk assessment found no human or ecological potential impacts from the use of these larvicides.

7.8.2.2 Special Considerations Regarding Human Breast Cancer

Bti and Bs, because they target receptors not found in mammalian guts, are assumed to be nontoxic to humans. Based on results of feeding studies in both rats and mice, which exhibited no increase in tumor incidence, USEPA concluded that methoprene is not carcinogenic (USEPA, 2001a), and so it cannot be a cause of breast cancer.

7.8.2.3 Special Considerations Regarding Potential Toxicity to Children

Bti and Bs, because they target receptors not found in mammalian guts, are assumed to be nontoxic to all humans, including children. Evaluation of the toxicity of methoprene by the USEPA indicates that exposure through oral, dermal or inhalation routes is not likely to cause adverse health effects in any human, including a child (USEPA, 2001a).

7.8.2.4 Long-Term Plan Field Work Results

Four field studies were conducted that looked for impacts associated with the use of larvicides to control mosquitoes. These were:

- the Caged Fish experiment, which tested the impacts of actual applications of methoprene on organisms in the field, and in the laboratory.
- the fate and transport work associated with the Caged Fish study. This does not directly determine impacts associated with methoprene, but may be important in future evaluations of potential impacts
- Benthic population evaluations, conducted as an off-shoot of the Caged Fish experiment, which sampled benthic populations in areas exposed to methoprene (and resmethrin) and those in areas not exposed to methoprene, and looked for differences using multi-variate statistics
- A keystone sampling experiment, in which three important marsh invertebrate organisms were sampled for in five pairs of marshes, to determine if long-term exposure to larvicides (Bti and methoprene) affected the abundance of the organisms differentially

The results of these studies were presented in Section 6.

In short, none of these experiments found any impact to the environment from exposure either to methoprene by itself, or in when methoprene and Bti were applied. The following details some of the results.

Caged Fish Experimental Results (Larvicide)

The original plan for this study called for all field work to be conducted prior to the beginning of August to avoid anticipated low DO events that are more prevalent during the hottest period of the summer. Unfortunately, due to many delays in obtaining permission to conduct the study, this was not possible. Preliminary data on caged fish and shrimp survival at all sites showed good survival during July. However, by the time the fully replicated study was performed, this was not the case. Periodic low DO was prevalent at the ditch site at Johns Neck and the ditch site at Timber Point used during the August 3 spray event (the cages were moved into more open water for subsequent spray events). Later in August, and for the early September spray, low DO was also a problem at the Havens Point reference site. These problems with low DO compromised the ability to detect toxicity that may have been due to pesticide exposure.

For methoprene, reduced fish survival was observed at Johns Neck, as compared to Timber Point, which was also sprayed, and Havens Point and Old Fort Pond reference sites during the first preliminary test. Unfortunately, no DO measurements were made during this test, so it is not known whether or not low DO could have been a factor at Johns Neck. The reduced survival for shrimp observed at Johns Neck and Timber Point, as compared to the reference sites at Havens Point and Flax Pond during the larvicide spray on August 3 could be attributed to low DO alone. During the August 10 event, reduced survival was observed both at Johns Neck and at Havens Point, even though low DO should not have been a problem. For the September 1 application event, Timber Point (the only site that received pesticides on that date) showed the best survival of all the sites evaluated at that time. Although effects from low DO cannot be cleanly separated from the effects (or lack thereof) from methoprene applications, the data strongly suggest that the pesticides applications were not the determinant of whether the fish and shrimp survived or not.

The static renewal studies conducted in the laboratory, which used water collected 30 minutes post application from each site, had excellent survival in exposed shrimp.

Taken all together, these data do not present consistent evidence of toxicity due to methoprene to the exposed organisms. It is not clear, however, whether the pesticide applications in conjunction with other stressors, such as low DO conditions, might not result in greater mortality than would have occurred without pesticide applications. This experiment was not able to separate impacts from low DO and the pesticide applications. The notion that pesticides can have synergistic impacts in conjunction with other stressors is a current research topic that is attracting much interest. With frogs, for example, work has focused on synergy between pesticides and climatic interactions (Davidson et al., 2001), pesticides and predator interactions (Relyea and Mills, 2001; Relyea, 2004), infection prevalence and pesticide exposure (Kiesecker, 2002), and effects resulting from endocrine disruption (Hayes et al., 2003; Hayes et al., 2006), although conclusive findings are not common.

The absence of acute mortality due to larvicide exposure is not terribly surprising for the caged fish study. Methoprene acts as a hormone mimic and inhibits molting (CA-IC, 2004). As such, in short term tests it would not be expected to kill adult shrimp, which molt only infrequently during the exposure period; nor should juvenile fish be affected by exposures.

Methoprene Fate and Transport

As part of the Caged Fish experiment, data were collected on the aquatic fate and transport of methoprene. Methoprene was applied in the micro-encapsulated, liquid form on the marshes. Testing showed that there was some transport of the chemical immediately into the ditches (as would be expected, as it was applied immediately overhead). Maximum concentrations of methoprene exceeding 1,000 ng/L (more than one part per billion) were observed 30 minutes post-application after three of four events; the highest concentrations were not always associated with surface film sampling, but sometimes came from sub-surface samples. However, two hours after applications, the concentration of methoprene was always less than 25 ng/L (parts per trillion). Very low but detectable concentrations (on the order of five parts per trillion) were sometimes measured a day or two after the applications. It appears likely it was transported to the bottom sediments, where the micro-encapsulation continued to degrade.

Methoprene was detectable one week after application in the sediments. Concentrations ranged from six to 60 ng/g (parts per billion), but repeated sampling in locations with repeated applications did not show increasing sediment concentrations. The best explanation for this result is a half-life of less than one week for the compound in the environment. If its half-life were even as long as one week, it would begin to accumulate with repeated applications, following the simplistic model in Table 7-13.

Table 7-13. Methoprene Sediment Concentrations Model, One Week Half-life, and One Week Application Intervals (unit-less measures)

Day	Input	Sediment Concentration
1	1	1
7		0.5
8	1	1.5
14		0.75
15	1	1.75
21		0.825
22	1	1.825
23		0.9125

The residual concentrations (and all sediment concentrations in general) keep rising based on this model. As that was not was detected in the Caged Fish sampling, it is clear that the half-life of methoprene is less than seven days in sediments.

Caged Fish Benthic Sampling

Timber Point, one of the two treatment sites in this study, received only larvicide treatments in 2004. Johns Neck received larvicides and adulticide applications in 2004. Therefore, the combined statistical analysis of treatment sites against control sites conducted on benthic samples does not clearly determine the impact of larvicide treatments alone. However, the study found no statistical difference between treatment and control sites, which suggests the larvicide treatments alone could not have been responsible for any impacts to the benthic populations.

The pairwise comparisons often found significant differences between one control site, Havens Point, and the treatment sites. This may be explained by substrate differences, which apparently did exist between the sites. It is clear that differences in sediment types leads to differences in benthic invertebrate populations (Cerrato et al., 1989).

That significant differences were also found between the two control sites under some of the statistical tests suggests the pesticide applications were not the cause of differences in populations and abundances. Therefore, this experiment does not find any impacts to the tested benthic invertebrate populations associated with larvicide use.

Keystone Species Sampling

This was a limited sampling effort. The power of the study would have been enhanced if the original design had been followed, where differences in larvicide applications may have been more pronounced, and if all of the pairs had treatment differences. However, the limited data collected here implies that long-term, persistent use of modern larvicides appears to have no impact on populations of these signature invertebrates.

Sampling for invertebrates is labor-intensive. Patchy populations may result in sampling artifacts that control the reported results. Diversity indices are sometimes preferred to abundance measures. However, the few studies that reported effects from mosquito larvicides found that changes in abundances were more measurable than changes in diversity (e.g., Hershey et al., 1998). Therefore, if measurements of abundances did not find impacts, then measuring diversity would probably not have found any impacts either. Therefore, this limited sampling effort seems to confirm that larvicide use, as currently practiced by SCVC, does not impact marsh invertebrates.

7.8.2.5 Additional Considerations Regarding the Toxicity and Potential Ecological Impacts of Methoprene

It is not disputed that methoprene can be toxic to aquatic organisms at great enough concentrations, so much so that the manufacturer of methoprene product must so state on the pesticide label (see, for example, Wellmark International, 1998). It is also true that measurements during the Caged Fish experiment detected methoprene in ambient waters at concentrations greater than one ug/l (ppb), which might be a threshold under some conditions for impacts to crustaceans (see Walker et al., 2005b). However, the greater than one ppb concentrations were not measured except immediately following the applications (less than two hours after application), and experimental findings of impacts required exposures of up to 72 hours, according to Walker et al. Since the higher Caged Fish measurements were not persistent, but the experiments recording impacts relied on sustained exposures, the conclusion of no grounds for impact is supported..

The primary research for the Impact Assessment (primarily, CA-IC [2004], CA-SCDHS [2005], and Cashin Associates (2005c) and this section of the DGEIS did not reference all literature produced on methoprene. As indicated in the project workplan (incorporated by reference into the EIS Scoping, see Appendices D and E), CA (and its subconsultant, Integral Consulting) was to rely on the literature discussion in the New York City (NYCDOH, 2001) and Westchester County (Westchester, 2001) EISs for pre-2001 toxicological information, and would conduct its own literature search in the post-2001 literature.

Communication from Kevin McAllister (letter to the TAC, dated March 17, 2005, and verbal comments and written article list, presented to the TAC March 10, 2005) suggested that some important elements of the literature were overlooked. The two sets of references were somewhat different. The list presented in the letter are numbered 1 to 16, just below; other citations from the initial TAC meeting list are appended as (a) to (i), also just below.

1) Pinkney, AE, PC McGowan, DR Murphy, TP Lowe, DW Sparling, and LC Ferrington. 2000. Effects of the mosquito larvicides temephos and methoprene on insect populations in experimental ponds. *Environmental Toxicology and Chemistry* 19(3):678-684.

2) Niemi, GS, AE Hershey, L. Shannon, JM Hanowski, A. Lima, RP Axler, and RR Regal. 1999. Ecological effects of mosquito control on

zooplankton, insects, and birds. *Environmental Toxicology and Chemistry* 18(3):549-559.

3) Horst, MN, and AN Walker. 1999. Effects of the pesticide methoprene on morphogenesis and shell formation in the blue crab *Callinectes sapidus*. *Journal of Crustacean Biology* 19(4):699-707.

4) Hershey, AE, AR Lima, GS Niemi, and RR Regal. 1998. Effects of *Bacillus thuringiensis israelensis* (*Bti*) and methoprene on non-target macroinvertebrates in Minnesota wetlands. *Ecological Applications* 8(1):41-60.

5) McKenney, CL, and DM Celestial. 1996. Modified survival, growth and reproduction in an estuarine mysid (*Mysidopsis bahia*) exposed to a juvenile hormone analogue through a complete life cycle. *Aquatic Toxicology* 35(1):11-20.

6) Ahl, JSB, and JS Brown. 1990. Salt-dependent effects of juvenile hormone and related compounds in larvae of the brine shrimp, Artemia. *Comparative Biochemistry and Physiology, A* 95A(4):491-496.

7) Lee, BM, and GI Scott. 1989. Acute toxicity of temephos, fenoxycarb, diflubenzuson, and methoprene and *Bacillus thuringiensis* var. *israelensis* to the mummichog (*Fundulus heteroclitos*). *Bulletin of Environmental Contamination and Toxicology* 43(6):827-832.

8) Bircher, L., and E. Ruber. 1988. Toxicity of methoprene to all stages of the salt marsh copepod, *Apocyclops spartinus* (Cyclopoida). *Journal of the American Mosquito Control Association* 4(4):520-523.

9) Batzer, DP, and RD Sjogren. 1986. Potential effects of Altosid (methoprene) briquette treatment on *Eubranchipus bondyi* (Anostraca: Chiroccphalidac). *Journal of the American Mosquito Control Association* 2(2):226-227.

10) Laufer, H. 1982. *The Effect of Hormonal Pollutants on Aquatic Crustacea and the Surrounding Environment*. Institute of Water Resources, The University of Connecticut, Storrs, CT. 38 pp.

11) Wurtsbaugh, WA, and CS Apperson. 1978. Effects of mosquito control insecticides on nitrogen fixation and growth of blue-green algae in natural plankton associations. *Bulletin of Environmental Contamination and Toxicology* 19:641-647.

12) Costlow, JD, Jr. 1977. The effects of juvenile hormone mimics on development of the mud crab, *Rhithropanopeus harrisii* (Gould). pp. 439-457. In: Vernberg, FJ, A. Calabrese, FP Thurberg, and WB Vernberg (eds.). *Physiological Responses of Marine Biota to* Pollutants. Academic Press, New York, NY. 462 pp.

13) Christiansen, ME, JD Costlow, Jr., and RS Monroe. 1977. Effects of the juvenile hormone mimic ZR-515 (Altosid) on larval development of

the mud crab, *Rhithropanopeus harrisii* in various salinities and cyclic temperatures. *Marine Biology* 39(3):269-279.

14) Payen, GG, and JD Costlow. 1977. Effects of a juvenile hormone mimic on male and female gametogenesis of the mud crab, *Rhithropanopeus harrisii* (Gould) (Brachyura: Xanthidac). *Biological Bulletin, Marine Biology Laboratory, Woods Hole* 152(2):199-208.

15) Buei, K, S. Ho, T. Yamada, S. Gamo, and M. Kato. 1975. The effect of a juvenile hormone mimic, methoprene against mosquito larvae. *Japanese Journal of Sanitary Zoology* 26(2-3):105-111.

16) Celestial, DM, and CL McKenney, Jr. 1994. The influence of an insect growth regulator on the larval development of the mud crab, *Rhithropanopeus harrisii*. *Environmental Pollution* 85(2):169-173.

a) Walker, AN, P. Bush, T. Wilson, E. Chang, T. Miller, and MN Horst. 2005a. Metabolic effects of acute exposure to methoprene in the lobster, *Homarus americanus*. *Journal of Shellfish Research* 24(3):787-794.

b) Walker, AN, P. Bush, J. Puritz, T. Wilson, ES Chang, T. Miller, K. Holloway, and MN Horst. 2005b. Bioaccumulation and metabolic effects of the endocrine disruptor methoprene in the lobster, *Homarus americanus*. *Journal of Integrative and Comparative Biology* 45(1):118-126.

c) Olmstead, AW, and GL LeBlanc. 2001. Low exposure concentration effects of methoprene on endocrine-regulated processes in the crustacean *Daphnia magna*. *Toxicology Sciences* 62(2):268-273.

d) Yasuno, M. and K. Satake. 1990. The effects of diflubenzuron and methoprene on the emergence of insects and this density in an outdoor experimental stream. *Chemosphere* 21(10-11):1321-1335.

e) Cehllayan, S. and GK Karnavar. 1989. Juvenile hormone induced ovipostion in virgin *Trogoderma granarium* (Dermestidac: Coleoptora). *Entomon* 14(3-4):187-190.

f) Sjogren, RD, DP Batzer, and MA Juenemann. 1986. Evaluation of methoprene, temephos, and *Bacillus thuringiensis* var. *israelensis* and *Coquillettidia perturbans* larvae in Minnesota. *Journal of the American Mosquito Control Association* 2(3):276-279.

g) Templeton, NS, and H. Laufer. 1983. The effects of a juvenile hormone analog (Altosid ZR-515) on the reproduction and development of *Daphnia Magna* (Crustacea: Cladocera). *International Journal of Invertebrate Reproduction* 6(2):99-110.

h) Brown, TM, and AWA Brown. 1980. Accumulation and distribution of methoprene in resistant *Culex pipiens pipiens* larvae. *Entomological Experimental Applications* 27(1):11-22.

i) Quistad, GB, DA Schooley, LE Staigner, BJ Bergot, BH Sleight, and KJ Macek. 1976. Environmental degradation of the insect growth regulator methoprene. 9. Metabolism by bluegill fish. *Pesticides Biochemistry and Physiology* 6(6):523-529.

An initial review of these references found that they were:

- substantively included in the Ecotoxicology review (CA-IC, 2004)
- not relevant
- not yet published at the time of the completion of Literature Search Book 7 (October 2005) and initial submission of the Impact Assessment (October 2005)

Table 7-14 summarizes and fully documents the technical review performed by Integral Consulting of these citations. All 16 of the March 17 citations (1-16), and seven additional citations from the first submission (c-i) were reviewed. Two papers by Walker et al. (the Horst research group, University of Georgia) (citations listings a and b) were also reviewed in manuscript form, courtesy of Dr. Horst (they had not yet been published when this work began, April 2005).

Table 7-14. Critical Review of Additional Methoprene Articles

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
1	Pinkney *et al.* 2000	(abstract obtained and reviewed by Integral for Literature Review)	X	Pinkney *et al.* observed no significant differences between Altosid treated ponds and control ponds based on mean insect emergence (all insects combined), though some "isolated" differences were observed in 2 of 18 ponds when springtails were not considered in overall emergence. Cluster analyses indicated Altosid ponds were most similar to control ponds. These findings are consistent with previously reported results for field studies conducted in Wright Count, MN indicating no significant long-term impacts on aquatic insects. Application rate and predicted nominal surface water concentrations are comparable to those used and predicted in Integral's risk assessment. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment are provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
2	Niemi *et al*. 1999	X	X	Methoprene application rates used in this study were 200-800 times higher than those in use in Suffolk County and evaluated in Integral's risk assessment. Overall, no significant long-term effects were identified for zooplankton or birds. Significant reductions were observed for mean aquatic insect biomass, density and richness during the latter half of the study (1992-1993), though no significant differences were observed from 1989-1991. The ecological significance of the latter effects remain uncertain, given that no food web impacts (i.e., impacts to foraging insectivorous birds) were observed. The authors contend that many additional years of study would be required to conclusively assess potential long-term insect biomass and food web effects. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
3	Horst and Walker 1999	(abstract obtained and reviewed by Integral for Literature Review)	X	Methoprene experiments were conducted using concentrations 15-500 times higher than those predicted under conservative, worst case conditions in Integral's risk assessment. Biochemical changes were observed in vitro, indicating effects to molting blue crabs may occur. Morbidity and mortality were observed during in vivo experiments on larvae at a concentration of 0.6 ppm (30-200 times higher than those predicted under conservative, worst-case conditions in the risk assessment). The overall dose response relationship associated with effects was not evaluated. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
4	Hershey *et al.* 1998	X	X	Hershey *et al.* (1998) conducted field experiments during 1991-1993 on the effects of methoprene on non-target macroinvertebrates in wetlands of Wright County, Minnesota. Effects were observed for methoprene in 1992, predominantly among chironomids and dipteran and non-dipteran insects. As a series of follow-up studies to the Hershey et al. (1998) work, as well as the companion work reported by Niemi et al. (1999), the Metropolitan Mosquito Control District of St. Paul Minnesota conducted additional experiments in Wright County. This more detailed work showed no long-term impacts from methoprene on total macroinvertebrate density or biomass and no difference in overall chironomid numbers between treated and untreated areas. Additional analysis suggested that the earlier declines observed in 1992 by Hershey et al. may have been attributable to higher than planned doses and to drought conditions which prevailed several years prior to the study (Balcer et.al., 1999; Read, 2001).

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
5	McKenney and Celestial 1996	X		McKenney and Celestial (1996) report on effects of methoprene to mysid shrimp under laboratory conditions. Experimental concentrations ranged from ~2 mg/L to 125 mg/L. These concentrations are not considered environmentally relevant based upon the conservative and worst case concentrations predicted in Integral's risk assessment (which were up to 4 orders of magnitude lower than those reported in this article). The overall dose response relationship associated with effects was not evaluated. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
6	Ahl and Brown 1990	(abstract obtained and reviewed by Integral for Literature Review)	X	Ahl and Brown (1990) report on the effects of methoprene to larval brine shrimp under laboratory conditions. Concentrations of methoprene in the range of 10^{-5}-10^{-7} M resulted in increased mortality and effects on molting. These concentrations are 1-4 orders of magnitude higher than the conservative and worst case concentrations predicted in Integral's risk assessment. Although a dose response relationship was determined, the effect of hypertonic saltwater concentrations (which elicit osmoregulatory stress and affect the ability to molt) were not factored. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.
7	Lee and Scott 1989	(abstract obtained and reviewed by Integral for Literature Review)	X	Lee and Scott (1989) was previously summarized as part of the Book 7 Task 3 ecotoxicological review. The mean LC50 for mummichog of 125,000 ug/L cited in Lee and Scott (1989), as summarized in USEPA's ECOTOX, is presented in ERA Appendix D of Integral's risk assessment.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
8	Bircher and Ruber 1988	(abstract obtained and reviewed by Integral for Literature Review)	X	Bircher and Ruber (1988) report on methoprene effects to copepod under laboratory conditions. Acute lethality (LC50) ranged from 800 ug/L - 10,000 ug/L depending on life history stage. The acute TRV utilized in Integral's risk assessment of 20 ug/L for daphnids is 40-500 times lower (i.e., more conservative) than the LC50s presented in this article. The authors conclude that at the range of concentrations effective for mosquito control, some transient decreases are possible, but no impacts are expected to copepod populations as a whole.
9	Batzer and Sjogren 1986	X	X	Batzer and Sjogren (1986) report on the potential effects of methoprene to brine shrimp under laboratory conditions. The overall dose response relationship associated with effects was not evaluated. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
10	Laufer 1982	(abstract obtained and reviewed by Integral for Literature Review)	X	Laufer (1982) reports on the effects of methoprene to daphnids and spider crabs under laboratory conditions. 100% percent mortality was observed for daphnids at concentrations ranging from 1.6 - 3.2 x 10^{-5} M. These concentrations are up to an order of magnitude higher than the conservative and worst case concentrations predicted in Integral's risk assessment. These concentrations are also 200-500 times higher than the acute TRV of 20 ug/L used for crustaceans in Integral's risk assessment. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
11	Wurtsbaugh and Apperson 1978	(abstract obtained and reviewed by Integral for Literature Review)	X	Wurtsbaugh and Apperson (1978) report on the potential effects of methoprene on blue-green algae growth and nitrogen fixation under laboratory conditions. Nitrogen fixation and production of chlorophyll a markedly differed from controls (were higher) at a test concentration of 500 ug/L. The authors conclude that these increases in the lab could either be attributable to direct effects associated with methoprene exposure, or indirect effects associated with hypothesized (but not measured) reductions in predatory zooplankton predators. The overall dose response relationship associated with effects was not evaluated. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
12	Costlow 1977	(abstract obtained and reviewed by Integral for Literature Review)	X	Costlow (1977) reports on the potential effects of methoprene on survival and development of mud crab larvae under laboratory conditions. Complete mortality was observed at the highest test concentration of 1,000 ug/L. This concentration is 50 times higher than the acute TRV for crustaceans used in Integral's risk assessment. Sublethal effects were not observed below 100 ug/L under salinity gradients of 20-25 ppt (100 ug/L is approximately 4 times higher than the chronic TRV for crustaceans used in Integral's risk assessment). At low salinity (i.e., 5 ppt), reduction in larval survival was observed at 0.1 - 10 ug/L. The author speculates that under stress conditions, these lower concentrations of methoprene may be associated with effects. However, reduced survival was additionally observed at low salinity for control populations. The overall dose response relationship associated with effects was not evaluated. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
13	Christiansen *et al.* 1977	(abstract obtained and reviewed by Integral for Literature Review)	X	Christiansen *et al.* (1977) reports on the potential effects of methoprene on survival and development of mud crab larvae under laboratory conditions. Complete mortality was observed at the highest test concentration of 1,000 ug/L. This concentration is 50 times higher than the acute TRV for crustaceans used in Integral's risk assessment. Sublethal effects (i.e., metamorphosis changes) were not observed below 100 ug/L. The authors speculate that observed effects on survival and development occurring with increased concentrations of methoprene were most likely related to stress conditions (e.g., low salinity and temperature). No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
14	Payen and Costlow 1977	X	X	Payen and Costlow (1977) report on the potential effects of methoprene on gametogenesis and inhibition of vitellogenesis and spermatogenesis of mud crab under laboratory conditions. The authors identify effects at 1,300 ug/L methoprene. This concentration is approximately 60 times higher than the chronic TRV used in Integral's risk assessment. The overall dose response relationship associated with effects was not evaluated. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.
15	Buei *et al.* 1975	(abstract obtained and reviewed by Integral for Literature Review)	X	This article is in Japanese, although the tables and figures are presented in English. Apparently, Buei *et al.* (1975) report on the efficacy of methoprene for control of mosquito larvae under simulated field application conditions. This article is not relevant to the evaluation of non-target ecological receptors. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
16	Celestial and McKenney 1994	X	X	Celestial and McKinney (1994) report on the potential effects of methoprene to mysid shrimp under laboratory conditions. The information provided in this article is equivalent to that reported by McKenney and Celestial (1996) (reviewed above). No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment we re provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
a	Walker *et al*., 2005a		X	Walker et al. (2005a) report on the potential effects of methoprene on survival, bioaccumulation, and biochemical changes in lobster under laboratory conditions. Acute toxicity was observed in 90% of test animals (stage IV larvae) for exposures of 50 ug/L methoprene. This concentration is 2.5 times higher than the acute TRV for crustaceans used in Integral's risk assessment. Bioaccumulation was observed in various tissues based upon a maintained concentration of 50 ug/L methoprene dissolved in acetone. However, this maintained laboratory concentration does not fully reflect potential environmental concentrations of methoprene based upon methoprene's low aquatic persistence (i.e., k_{total} = 0.23 day^{-1}) and high degree of partitioning to sediment and suspended solids. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
b	Walker *et al*., 2005b		X	Walker et al. (2005b) report on the potential effects of methoprene on survival, bioaccumulation, and endocrine effects in lobster under laboratory conditions. Acute toxicity was observed in 30% of test animals (stage II larvae) using 1 ug/L methoprene. Increased molting was observed at > 5 ug/L for stage IV larvae. Both effects were observed over a 72 hour period using methoprene dissolved in acetone. Maintained laboratory concentrations may not fully reflect potential environmental concentrations of methoprene based upon its low aquatic persistence (i.e., $k_{total} = 0.23$ day^{-1}) and high degree of partitioning to sediment and suspended solids under natural conditions. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article. It is noted that if an acute TRV of 1 ug/L was used in Integral's risk assessment in place of the selected 20 ug/l, the overall risk findings for methoprene would not change (all predicted hazard quotients would remain well below 1).

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
c	Olmstead and LeBlanc 2001	X	X	Olmstead and LeBlanc (2001) report on the potential effects of methoprene on endocrine mediated endpoints associated with development and reproduction in daphnids under laboratory conditions. Juvenile daphnid growth was reduced at a threshold of 12.6 nM. Other reproductive endpoint effects were observed at 32 nM (NOEC for endocrine-mediated processes associated with maturation). These concentrations are approximately 5-10 times higher than the chronic 42 day NOEC of 27 ug/L used for crustaceans (lowest value among all freshwater invertebrates) in Integral's risk assessment. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
d	Yasuno and Satake 1990	X	X	Yasuno and Satake (1990) report on the potential effects of methoprene on mortality and emergence of freshwater benthos in outdoor experimental streams. Prepared concentrations of methoprene ranged from 1,000 - 10,000 ug/L. This range of concentrations did not result in any observed mortality effects to benthos, though the authors were not able to identify the presence of chironomids and caddisflies. The range of concentrations used in this outdoor experiment were 3-4 orders of magnitude higher than the conservative and worst case concentrations predicted in Integral's risk assessment. These concentrations are also 50-500 times higher than the acute TRV of 20 ug/L used for crustaceans (lowest value among all freshwater invertebrates) in Integral's risk assessment. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
e	Chellayan and Karnavar 1989	(abstract obtained and reviewed by Integral for Literature Review)	X	Chellayan and Karnavar (1989) report on the potential effects of methoprene administered to dermestid beetles under laboratory conditions. Beetles at various stages of growth were dosed with methoprene using topical applications. Methoprene was observed to induce oviposition absent mating. Dosages are reported on a mass of methoprene per insect (i.e., ug/insect). Topical application and the reported doses are not environmentally relevant for the assessment of aquatic exposures and risks. In addition, methoprene is applied directly to water and not to terrestrial habitats. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
f	Sjogren *et al.* 1986	(abstract obtained and reviewed by Integral for Literature Review)	X	Sjogren *et al.* 1986 report on the efficacy of methoprene for control of mosquito larvae under simulated field application conditions. This article is not relevant to the evaluation of non-target ecological receptors. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.
g	Templeton and Laufer 1983	(abstract obtained and reviewed by Integral for Literature Review)	X	Templeton and Laufer (1983) report on the potential effects of methoprene on survival and growth of daphnids under laboratory conditions. The lowest reported concentration associated with effects (i.e., $3.2x10^{-7}$ M, embryonic development) is approximately a factor of 5 higher than the acute and chronic TRV for freshwater crustaceans used in Integral's risk assessment. The overall dose response relationship associated with effects was not evaluated. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Article	Author(s)	Previously Reviewed under NYC EIS or Westchester EIS	Full article review post March-2005	Review and Discussion
h	Brown and Brown 1980	X		Brown and Brown (1980) report on the accumulation and distribution of methoprene in mosquito larvae. This article is not rele vant to the evaluation of non-target ecological receptors. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.
i	Quistad *et al.* 1976	X	X	Quistad *et al.* (1976) report on the metabolism of [5-14C] methoprene in bluegill sunfish. Whole fish analyses showed that hydroxy ester was the main metabolite, with the residues most prominent in muscle tissue. Overall, it was demonstrated that while methoprene can be accumulated, accumulated residue is rapidly eliminated by fish. No additional ecotoxicity data or environmental data beyond those considered in Integral's risk assessment were provided by this article.

Review of the New York City (NYCDOH, 2001) and Westchester County (Westchester, 2001) EISs by Integral Consulting and SCDHS found these documents to appear to be somewhat incomplete in their reviews of the literature. However, nine of the articles were cited in the Westchester County or New York City EISs. The information presented in them had already been incorporated in the data sets used by the risk assessor. They may not have been explicitly cited in the Ecotoxicology review (CA-IC, 2004) because the information contained in them may have been duplicative of other sources or the concentration or effect found may not have been as toxic as other articles found.

To address the potential shortcomings of the EISs research, Integral Consulting obtained abstracts of seemingly relevant research that was not referenced in the EISs (as did SCDHS for its preparation of the Human Health Toxicology Literature Review [CA-SCDHS, 2005]). Reviews of most abstracts suggested that the substance of the EIS reviews covered the information in the uncited articles. Many of the listed articles are cited in other articles that were referenced in the Ecotoxicology report (CA-IC, 2004) (as might be surmised, given the age of some of the papers on the lists). As noted in the comments in Table 7-14, some of the articles turned out not to be especially relevant or usable. In any case, Integral Consulting believes its toxicology assessment research covered all of the pre-2000 citations above.

The more recent references included on the lists include Pinkney et al (2000) and Olmstead and LeBlanc (2001). The two Walker et al. studies were not published until late in 2005. The Pinkney article is generally in agreement with the findings of the risk assessment, and the Olmstead and LeBlanc article used a higher concentration (i.e., a less toxic value) for impacts than the Integral Consulting risk assessment did. Therefore, their absence from the Ecotoxicology review and the absence of these findings in the risk assessment did not impact the discussion at all.

The findings from the two Walker et al. studies were not included in the risk assessment work. Integral's analysis of these two articles did note that the one ug/l threshold for impacts found in Walker et al. (2005b), for 30 percent mortality in Stage II lobster larvae, and the greater than five ug/l concentration for delayed molting in Stage IV larvae from Walker et al. (2005a), are less than the 20 ug/l threshold for crustacean impacts used in the risk assessment. Integral Consulting thus re-evaluated the potential for impacts using a one ug/l crustacean impact threshold. The quantitative analysis continued to find that methoprene applications to fresh water wetlands and salt marshes by SCVC, at the rates described on the methoprene label, should not result in any non-target organism impacts. This conclusion is based on the finding that even with a TRV of one ppb, all hazard quotients remained well below one (which is the determinant of whether any risk of an impact exists).

However, Integral Consulting noted that the use of one ug/l as an acute TRV for methoprene would most likely be considered inappropriate under standard risk assessment protocols. The one ppb value resulted in 30 percent mortality among Stage II larvae over 72 hours with maintained concentrations. It thus is not an LC_{50} (the concentration resulting in the acute mortality of 50 percent of the organisms), which is the standard aquatic toxicological value used in ecological risk assessments, because it is dose dependent and statistically derived.

In addition, it is not reasonable to find a steady-state, maintained concentration of methoprene in a natural water body, at least one derived from dissolution of the material into the water column, based on the short aquatic half-life derived from its high propensity to sorb onto organic matter (this mechanism removes the chemical from the water column) (see Cashin Associates, 2005d). Methoprene is intended to maintain a lethal concentration in the water column over an extended period of time, through continuous dissolution of the microencapsulated particles. Such concentrations will be much less than the concentration derived from application rates. However, this is the experimental protocol used by the Horst laboratory. The addition of acetone to the water column under the reported experimental procedures maintained the methoprene in solution longer than it would have under ambient conditions. It should also be noted that the concentration derived by Walker et al. for "field applications" of methoprene seem to depend on all of the applied methoprene dissolving into the water. Not only is methoprene quickly scavenged from the water column due to its high K_{ow} of more than six (meaning the chemical is approximately a million times more attracted to organic matter than it is to water) (Cashin Associates, 2005e), but it is often delivered in an encapsulated form (intended to result in time release of methoprene, maintaining a fractional concentration of the delivered amount of pesticide in the water column over a longer period of time). The researchers therefore appeared to try to consider two contradictory aspects of an application at once: they set the concentration as if all the applied methoprene was released into the water column at once, but they then maintained that concentration as if the chemical were undergoing a time release to sustain a particular concentration. In other words, the experiments used a methoprene concentration that could only be achieved if all the methoprene dissolved at once, and then maintained that concentration as if no dilution, scavenging, or degradation of the methoprene takes place over the next 72 hours. The scientific literature and data collected by Suffolk County indicates that this is not how methoprene behaves.

The sampling undertaken as part of the Early Action projects (Cashin Associates, 2005d) and USGS sampling in 2002 through 2004 (CA-USGS, 2005) found that the only methoprene concentrations exceeding one ppb were measured within two hours of applications, and samples taken at longer after an application was made was much lower in concentration (tens of parts per trillion [ppt]). Sampling in Washington State in 2005 also found similar results. Only six percent of samples (five of 72), taken at various intervals post-application in water bodies undergoing regular (weekly) methoprene applications, had detectable amounts of either methoprene or methoprene acid (detection limits reported to be approximately 0.1 ppb). All detections were less than 1 ppb. Four of the positive results occurred on the day or next day after applications. One detection occurred nearly a week later (and, at 640 ppt for methoprene and 520 ppt for methoprene acid, represented the highest levels measured in the program, but still below the concentrations maintained by the Horst group) (Johnson and Kinney, 2006).

7.8.2.6 Impacts of Application Methods

Approximately 4,000 acres of the County's salt marshes receive aerial applications of larvicides under the present program. The County uses a helicopter to fly at low (circa 20 feet) elevations at fairly rapid speeds (approximately 75 mph) for these events. It has been reported that the helicopter often flushes birds from the marsh.

It is difficult to determine, based on published literature, the effects of this flushing on birds in general, and so impossible to determine the effect on any species in particular. Work has been accomplished regarding the impacts on birds of constant take-offs and landings at airports, but the situations are not analogous. Most impacts at airports are considered to be minimal, as the birds become accustomed to the pattern of flights. Larviciding happens at long enough intervals (almost always at least one week between events, and sometimes longer) that it is unlikely that the startle reflex can be suppressed. Some marshes may receive a dozen (or slightly more) applications in a particular season. This means that the incidence may be often enough to have an impact.

Studies associated with low frequency or single approaches, especially by helicopter, suggest that impacts vary by species, with some water fowl especially being noted as reacting more than, say, raptors (Edwards et al., 1979). Losses due to nest disturbance were greater during egg-laying and incubation times than for nestlings, although disturbances can lead to premature fledging (White and Sherrod, 1973). However, most birds disturbed from nests returned within five minutes (Kushlan, 1979), potential predators and other human approaches caused as much startling as helicopter overflights (Ward et al., 1986), and some birds startled more frequently with no apparent cause as they did in response to aircraft (Dunnet, 1977). Helicopters are more disturbing than fixed wing planes (Gunn and Livingstone, 1972), but jet engines cause more disturbance than piston engines. Effects can be reduced by approaching from upwind under fair weather conditions so that the surprise factor is reduced (White and Sherrod, 1977).

It appears that impacts associated with larviciding are akin to startling caused by predators. Startling by predators can cause certain species to abandon nests – piping plovers are an example, as many Long Islanders are aware. For most species, however, unless the startle occurs at a key moment, the effects do not appear to be fatal to either eggs or brooding parent.

The County lacks pertinent data to offer any meaningful change in current operating procedures. The County would accept details from informed sources regarding any birds that may be at risk from infrequent startling, especially if the information includes the periods of greatest susceptibility. For example, SCVC has modified flight paths to ensure beaches occupied by nesting piping plovers are not overflown by its helicopter, even when making turns at the end of a run, to minimize potential disturbances for that species. Other species of concern, if information can be compiled to suggest precautions are warranted, would receive similar consideration.

Similarly, the physical application of some larvicides, which can involve spraying particulates across a marsh, could conceivably cause damage to insects that are airborne when the application occurs. Again, local, specific information regarding any species that may have a mass emergence, mating flight, or similar activity that could place a population at risk at a particular time, is not readily available. The County has indicated in the Long-Term Plan that it wishes to work with those having this kind of information, especially as it relates to particular locations or habitat types, to develop strategies to minimize impacts from its operations.

7.8.2.7 Efficacy of the Current Program

General Studies

Bti applications in Rhode Island resulted in reductions in light trap counts (the trap was a quarter-mile from the marsh) of between 40 and 60 percent for salt marsh mosquitoes (*Ochlerotatus sollicitans*) from one year to the next; when Bti was applied at spots where breeding persisted after an OMWM project that constructed tidal creeks and fish ponds, the decrease from baseline conditions was from 85 to 95 percent (except on one occasion where the Bti was not applied in a timely fashion, and a brood resulted) (Christie, 1990). The reductions for *Oc. cantator* were not consistent. Bti was found to kill half of exposed *Anopheles quadrimaculatus* larvae in a liquid formulation applied at 7.6 ug/l (Milam et al., 2000) (note the standard application rate for Bti is an area formulation calculated in lbs/acre). Bti killed half of exposed *Culex spp*. mosquitoes from California at concentrations ranging from 0.006 to 0.017 ug/l, and 95 percent of the mosquitoes at concentrations ranging from 0.022 to 0.085 ug/l. *Cx. pipiens* mosquitoes from Cyprus had a 50 percent mortality at concentrations from 0.005 to 0.05 ug/l, and a 95 percent mortality rate for concentrations ranging from 0.026 to 0.325 ug/l (Wirth et al., 2001), illustrating that there is a great variability in the susceptibility of particular mosquito populations, even with one species. In Australia, mosquitoes from the genera *Aedes, Ochlerotatus,* and *Culex* were all controlled, with 48 hour mortalities exceeding 96 percent, even in highly organic waters, using a water-dispersible formulation of Bti. *Ochlerotatus* mosquitoes were slightly more tolerant of the pesticide. No residual effect was found one week after application (Russell et al., 2003).

Bti was found to be ineffective for most application means for the control of *Coquillettidia perturbans* in Minnesota, as only one formulation resulted in statistically significant differences between pre-treatment and post-treatment larvae means (the one application type reduced mean numbers by more than 50 percent) (Sjrogen et al., 1986). It also was not effective in Indiana against *Cq. perturbans* (Walker, 1987).

Methoprene reduced numbers of *Cq. perturbans* in Minnesota, with treatment areas having 60 percent fewer adults than untreated areas, and the difference being statistically significant, as measured using emergence cages. The dosage applied was less than five percent of the label rate (Sjrogen et al., 1986). It was also found to be reduce *Cq. perturbans* in Indiana, with a more than 80 percent reduction in emergence (Walker, 1987).

Suffolk County Efficacy Tests

The County tests the efficacy of selected larval applications by testing for live larvae after Bti applications, and conducting fly-up testing for methoprene. These results have not been cataloged, but anecdotal information confirms that the larvicides, by and large, achieve their purpose. An example of the effectiveness of Bti was shown when duplex applications (Bti and methoprene) were made to salt marshes at Timber Point and Johns Neck as part of the Caged Fish experiment. No live larvae could be found to test for methoprene effectiveness on one date.

Methoprene efficacy was shown in the testing at Johns Neck and Timber Point. Following a duplex application, 32 larvae and 75 pupae were collected; only one adult emerged, suggesting efficacy greater than 95 percent. When methoprene alone was applied, approximately 275 larvae were collected along with 20 pupae. Four adults emerged, again suggesting better than 95 percent mortality.

The County added methoprene to its larvicide program in 1995. Bti, as suggested above, was shown to be effective for specific applications, but did not seem to be providing an overall reduction in mosquito counts. The addition of methoprene did provide major reductions in counts, as measured using annual trap counts at six sites (five treatment areas and one control). overall, four of the traps showed counts reductions between 79 to 99 percent for salt marsh mosquitoes (*Ochlerotatus cantator*, *Oc. sollicitans*, and *Oc. taeniorhynchus*), comparing eight years of data pre-methoprene to nine years of data following its addition to the program (Figures 7-2 to 7-5). The fifth site, overall, had a 23 percent reduction in mosquitoes, but the trend was also sharply down for the first four years of the treatment before reversing itself in 2000 (Figure 7-6). The County attributes this to the proximity of untreated National Seashore marshes. The control site had essentially unchanged populations (Campbell et al., 2005).

Figure 7-2. Average Salt Marsh Mosquitoes For Seatuck

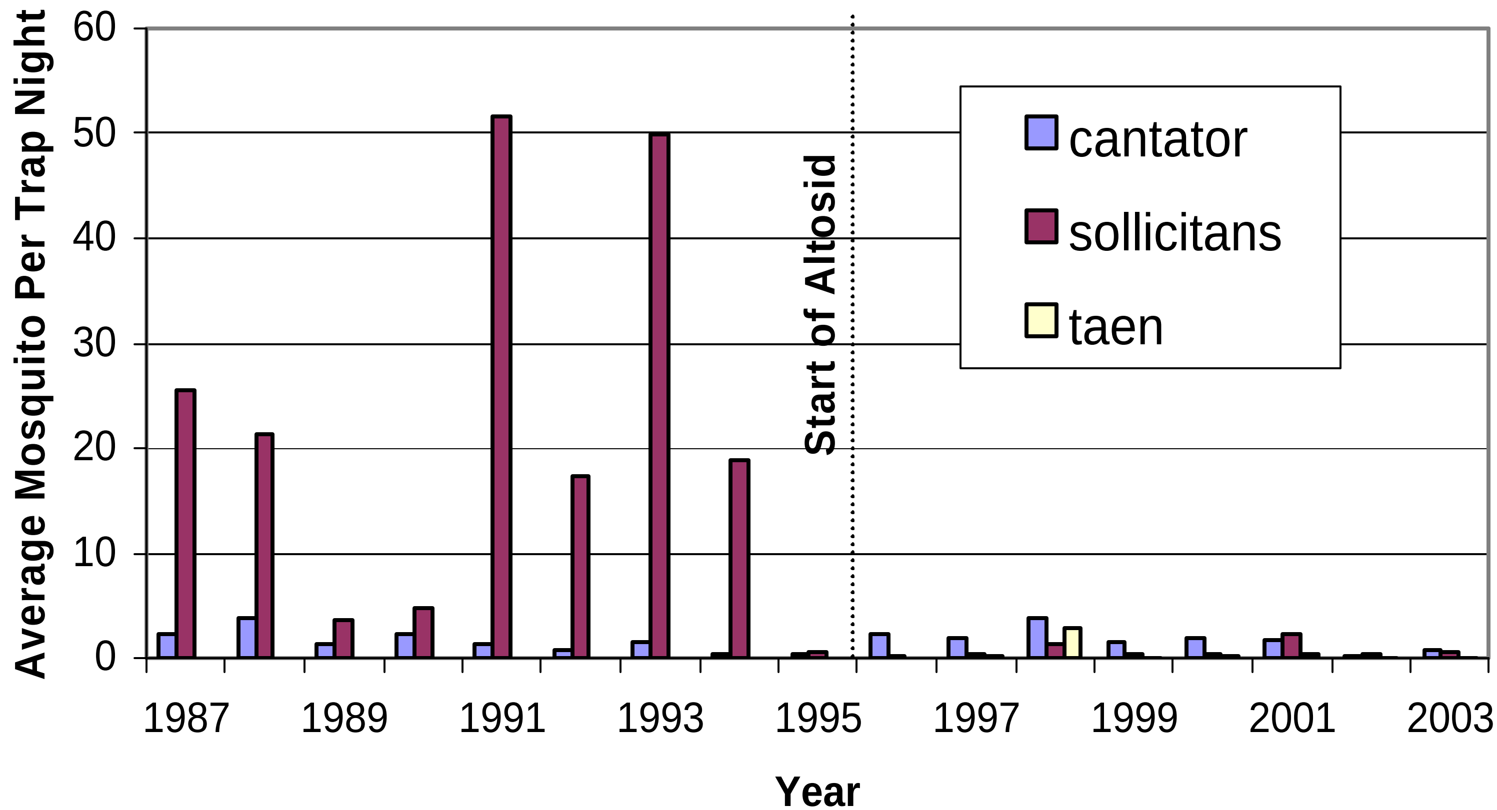


Figure 7-3. Average Salt Marsh Mosquitoes For Heckscher Park

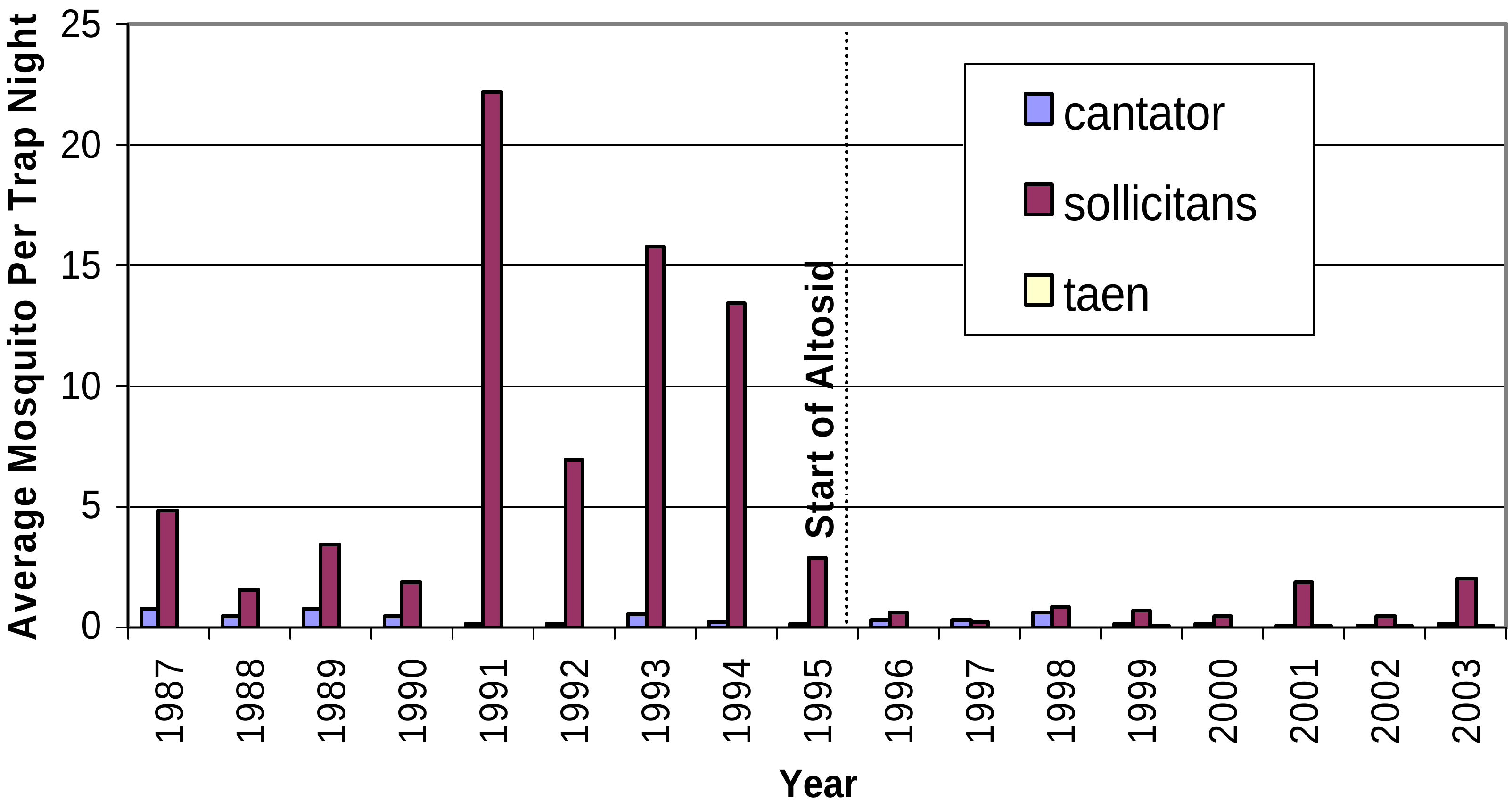
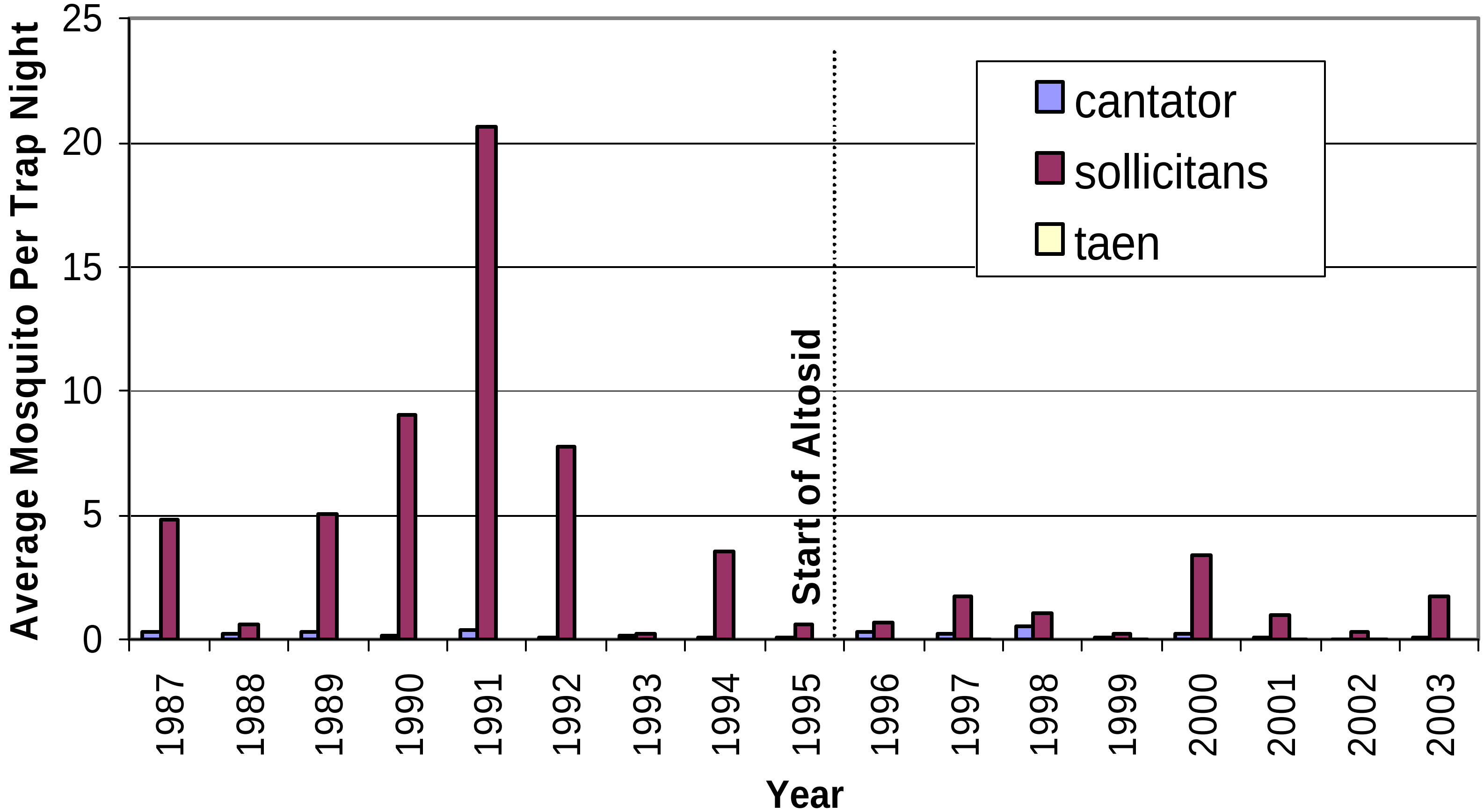


Figure 7-4. Average Salt Marsh Mosquitoes For West Sayville



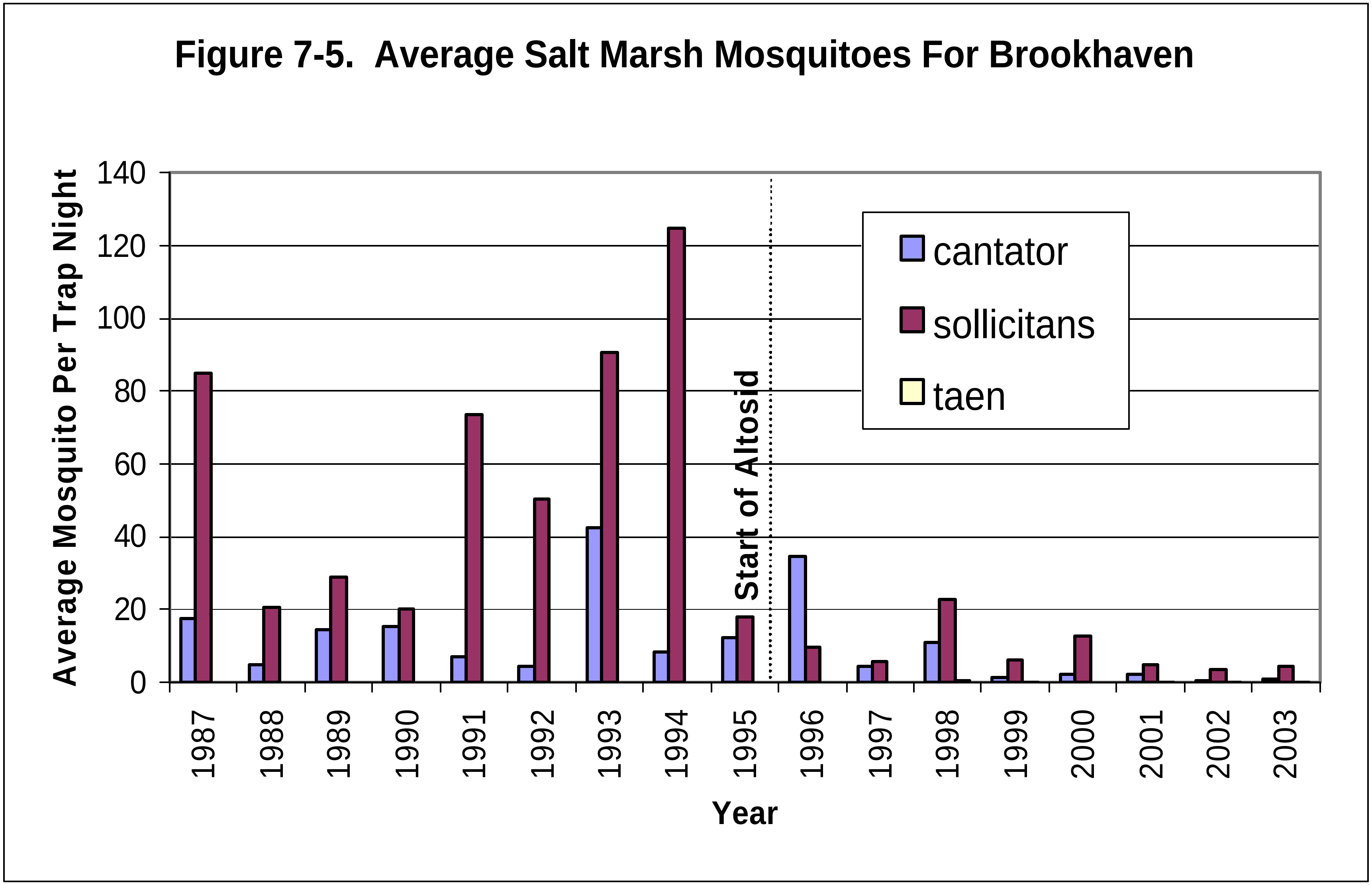


Figure 7-5. Average Salt Marsh Mosquitoes For Brookhaven
Average Mosquito Per Trap Night
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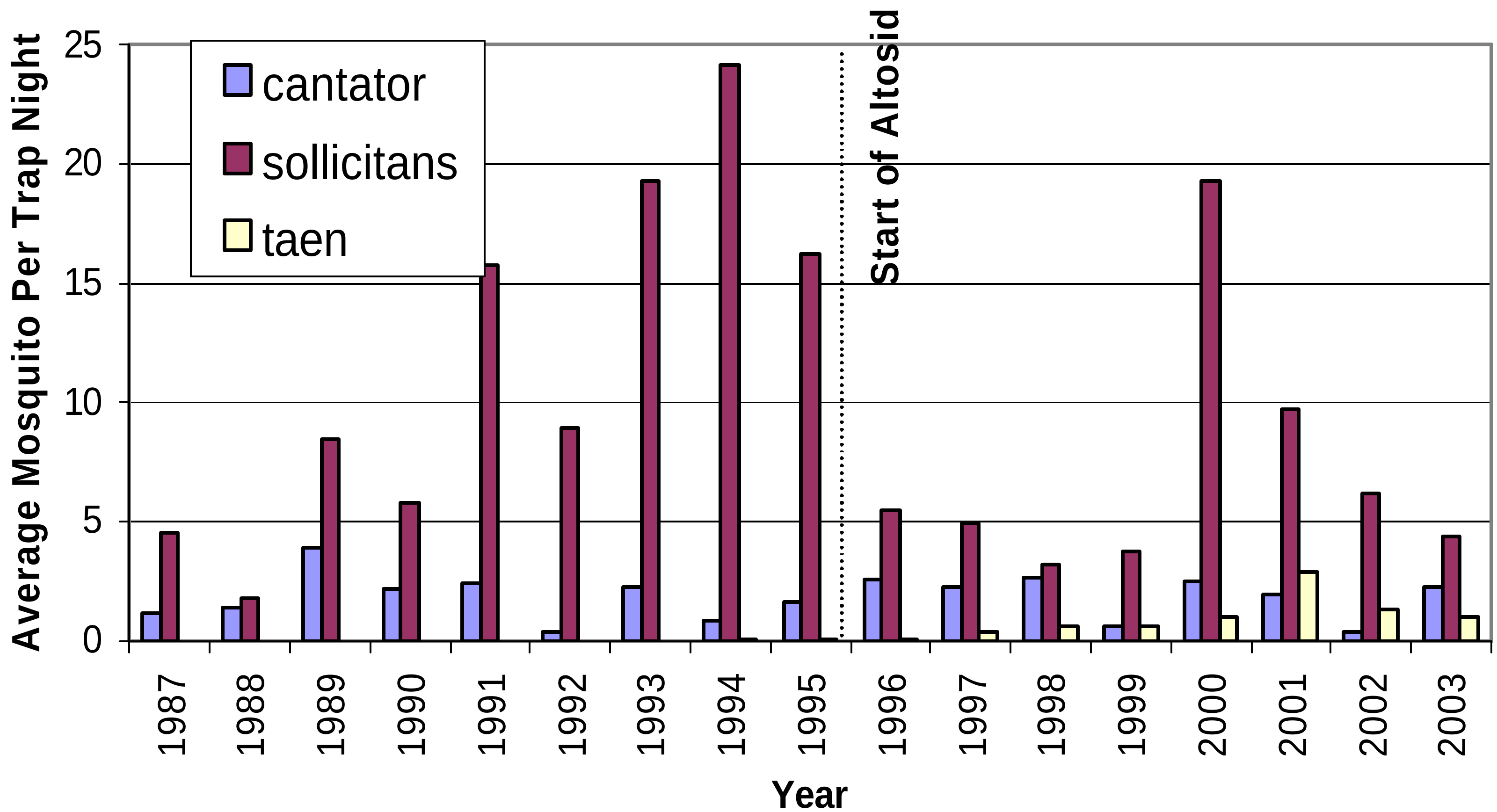
Figure 7-6. Average Salt Marsh Mosquitoes For Mastic Beach



7.8.2.8 Resistance Management

The current program manages its larvicide program to prevent resistance from developing in mosquito populations in several ways. One, there is rotation among the larvicide choices. Bti is often used early in the season. This is because Bti is effective against early instars (the larvae must be feeding in order for Bti to be effective). Cooler weather means the larvae develop more slowly, and so routine responses to larval presence generally still results in the younger larvae being treated. Bti is generally assumed to be extremely difficult to generate resistance to. This is because it generates five different toxins. A mutation offering protection against one toxin would need to develop concurrently with mutations against the other toxins in order for a mosquito to escape from Bti toxicity. This is thought to be improbable. Rotating methoprene in with the Bti, as is done in duplex applications, means another layer of immunity would need to be generated simultaneously.

Since methoprene has one mode of action, it is more likely that resistance could develop to it. This is addressed by using Bti whenever possible, and also through the use of duplex applications.

7.8.3 Long-Term Plan

Many of aspects of the proposed larval control program under the Long-Term Plan are similar to those of the current program. The strong requirement for surveillance evidence of breeding will be maintained, and, as conditions allow, indices to measure for breeding to identify problem breeding will be developed. The reliance on progressive water management, and the expected results from that program, mean that, in the long-term, portions of larval control efforts may be discontinued or greatly reduced in scope. For example, it is estimated that full implementation of the progressive water management program should lead to 75 percent reductions in the acreage of salt marsh aerial larviciding applications. Although it is not clear that larvicides have significant impacts on the environment, such advances would be in accord with general County policies promoting reduced use of pesticides whenever possible, reduce possible worker exposure and avoid potential accidents, and resolve problems associated with pesticides such as missed opportunities for applications due to weather or logistical situations, and sometime ineffective applications.

Other differences between the current program and the Long-Term Plan include:

- Expanded catch basin and recharge basin larviciding

It has been demonstrated that, generally, storm water control systems can be important breeding areas for mosquitoes, including those that may be important vectors of human disease (DeChant, 2005). Sampling undertaken as part of the Long-Term Plan development of catch basins and recharge basins that are not currently treated by the County found instances where breeding was occurring. Work in Los Angeles found that human cases of WNV were nearly eliminated when a focus on mosquito control in the storm water systems there was made, and that a few clusters of cases that did occur were explicable in terms of errors in the stormwater system control effort (Kluh et al., 2005). However, although this indicates that expanding the stormwater structure larviciding program in Suffolk County should produce positive results, the factors that led to such success in Los Angeles, including water availability and the mix of vector species, are not those found in Suffolk County, and so the level of success in WNV control is unlikely to be duplicated here.

- Efficacy testing

As resources allow, the County will make greater efforts to formally determine the effectiveness of all its pesticides use, including larvicides. The County has assurances that the larvicides are effective, in that a classic sequence of events is:

1) inspectors find larvae breeding
2) larvicides are applied
3) no mosquito problem in the area follows

Although it is possible that other factors resulted in the demise of the mosquitoes or the failure of the mosquitoes to pester people, to have this sequence occur consistently makes a strong case that the larvicides are effective in preventing adult emergences. However, more concrete data would allow managers to better analyze conditions under which particular larvicides work best in Suffolk County, and would also provide tangible evidence to present to the public regarding the effectiveness of the program.

- Implementation of ecological controls identified by Towns and other experts

Sensitive organisms and environments remain a concern for the County. This was the basis for the County in working with NYSDEC to identify tiger salamander habitats and to ensure that no pesticides were applied in those areas while breeding was occurring. This policy was adopted, although the preponderance of evidence is that amphibians are not at risk from mosquito control pesticides. There are no studies that directly test this hypothesis (see the discussion in the risk assessment, above, and expanded in Cashin Associates, 2005c), but, as developed in the risk assessment, the potential seems vanishingly small that there is such an impact.

However, there is still controversy regarding the role agricultural pesticides (especially atrazine) play in potentially causing frog deformities. Early links of these pesticides directly causing impacts to frogs seem to be in error. A trematode infection is clearly the cause of the deformities (Johnson et al., 2003; Kaiser, 2003). Discussions continue as to whether pesticides may be a synergistic factor in the infections (Kiesecker, 2002), or whether nutrients are much more of a factor (Johnson and Chase, 2004). It may even be more complicated, as the combination of agricultural stressors (nutrient and pesticide loading) may combine with other stressors (such as predators, see Relyea and Mills, 2004) to induce synergistic effects that cause impacts to frogs. Hayes et al. (2006) also believe that it is synergism between different chemicals, so that while testing of any individual chemical does not result in effects (or significant ot serious effects), several chemicals acting in concert replicate the apparent impacts to natural populations. Methoprene was not one of the pesticides tested by Hayes et al., in reaching that conclusion.

- Implementation of formal resistance testing and management

Although the possibility of resistance to larvicides appears low, because a good proportion of the County's salt marshes are treated with larvicides, it appears to be sound to incorporate formal resistance testing into the program. This specialized work will ensure that any tendency towards resistance to any of the three proposed larvicides is measured early, and then countermeasures can be adopted by the County to help maintain its arsenal of pesticides to control larval mosquitoes.

Larviciding is intended to, and as efficacy studies show, does reduce adult mosquito populations. This will reduce the potential for impacts from mosquito-borne disease. Use of larvicides was shown by the risk assessment and various field studies and literature searches to have no human health or apparent ecological impacts. In any case, the water management program adopted by the Long-Term Plan intends to reduce the area subjected to aerial larviciding applications on the order of 75 percent. The potential adoption of trigger values for applications could further reduce applications. Larviciding, in an of itself, has no demonstrable impacts to water management, although current regulations limiting water management in fresh water environments has the effect of promoting the use of larvicides there to reach mosquito control goals.

7.9 Impacts of the Long-Term Plan: Part 7, Adult Control

7.9.1 Introduction

This section discusses the impacts of the use of adult controls. The proposed Long-Term Plan will continue to use some adulticides previously used by SCVC (resmethrin, sumithrin, and malathion) and proposes to add two compounds to the list of potential pesticides (permethrin and natural pyrethrin). Other changes have been made to the program, as well, including modifications in adulticide-directed surveillance, decision-making procedures, and efficacy and resistance testing. Changes to the application methodology formerly used by the County will be discussed, although those changes have actually been implemented into the existing program. The application approach of the current program, to use adulticides where impacts to quality of life are considered unreasonable, and to protect human health by preventing mosquito-borne disease, follows the overall approach of the Long-Term Plan. This means that the quantitative risk assessment is applicable for the Long-Term plan program, although it is hoped that other aspects of the Long-term Plan will actually result in less need to apply adulticides.

Therefore, this section will solely discuss the approach adopted under the Long-Term Plan, and will identify potential impacts associated with the Long-Term Plan. This discussion will include the results of the quantitative risk assessment, as well as information gathered through the field programs and investigations of the scientific literature. This section will also discuss benefits that have been identified as occurring from the use of adulticides, from efficacy work conducted elsewhere but also some conducted in Suffolk County. The discussion of potential benefits will identify ways that the proposed Long Term Plan may reduce human health impacts from mosquito-borne disease compared to the current program.