Evaluation Monitoring for Stormwater Runoff Monitoring and BMP Development

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Abstract

This report covers the development and application of evaluation monitoring to highway, urban area and street stormwater runoff water quality management. A discussion is presented on the need for an alternative approach to the conventional approach of evaluating the water quality impacts of highway and urban area stormwater runoff on receiving water quality. Information is presented on the background to the development and application of site-specific studies (evaluation monitoring) that are conducted on the receiving waters for stormwater runoff that identify real water quality use impairments in these waters that are caused by chemical constituents and/or pathogenic organism indicators in the stormwater runoff.

The evaluation monitoring program is designed to replace the conventional "water quality" monitoring programs that are used for measuring the chemical constituents in highway, urban area and street stormwater runoff. It is widely recognized that conventional runoff water quality monitoring provides little in the way of useful information that can be used to evaluate the impact of stormwater runoff on the beneficial uses of the receiving waters for the runoff. Evaluation monitoring serves as a technically valid, cost-effective basis for BMP development that replaces the conventional approach that is used to develop stormwater runoff water quality BMPs. The conventional BMP development approach assumes that detention basins, grassy swales, various types of filters, etc. are effective BMPs in controlling real water quality use impairments due to heavy metals, organics and other constituents in highway and urban area stormwater runoff. However, it is now well-known that particulate forms of heavy metals and other constituents that are removed in conventional stormwater runoff BMPs do not adversely impact the beneficial uses of the receiving waters for the runoff. The particulate forms of heavy metals and other constituents are in non-toxic, non-available forms. Therefore, their removal in a detention basin will not be of benefit to the beneficial uses of the receiving waters for the stormwater runoff.

Basically, the evaluation monitoring program shifts the funds that are used for end-of-the-pipe runoff monitoring to site-specific, highly directed studies designed to find real water quality use impairments of the receiving waters for the stormwater runoff. When such use impairments are found that are due to highway, urban area or street runoff, then BMPs are developed that control the input of the pollutants, i.e. those constituents that cause impairment of the beneficial uses of the receiving waters for the stormwater runoff to the maximum extent practicable. The focus of BMP development is on source control

which limits the amount of pollutants entering the highway, urban area and street runoff at their source, rather than trying to treat the stormwater runoff. The evaluation monitoring approach is in accord with current regulatory requirements for highway, urban area and street stormwater runoff water quality management.

The evaluation monitoring program is designed to be a cooperative program in which the stormwater dischargers, regulatory agencies and those concerned about the water quality use impairment of the receiving waters for the stormwater runoff work together to formulate and implement the evaluation monitoring program in the most technically valid, cost-effective manner for utilization of the financial and other resources available.

A generic application of the evaluation monitoring approach for the development of stormwater runoff water quality management BMPs for a new highway is presented. This highway is being constructed without the conventional BMPs such as detention basins and/or filters. Instead, a critical evaluation has been made of the potential water quality problems that could arise from chemical constituents and pathogenic organism indicators in the highway stormwater runoff on the designated beneficial uses of the receiving waters for this runoff. When the highway becomes operational in the year 2000, site-specific studies will be conducted of each of the receiving waters for the highway runoff to determine what effect, if any, the highway runoff has on the designated beneficial uses of the receiving waters for the stormwater runoff. Consideration is given to such impacts as aquatic life toxicity, excessive bioaccumulation of hazardous chemicals in aquatic organisms, sanitary quality that impacts contact recreation and/or shellfish harvesting, excessive fertilization, oil and grease and litter accumulation, siltation, etc. Two types of stormwater runoff discharge situations are considered. One of these is a river; the other is an estuarine bay.

If the highway stormwater runoff is found to be a significant contributor to the impairment of the beneficial uses of these receiving waters, then the transportation agency responsible for managing highway stormwater runoff impacts will work with the regulatory agencies and others to develop best management practices that will control the impaired beneficial uses to the maximum extent practicable. The focus of the BMP development program will be on source control to limit the amount of the pollutants that enter the highway runoff at their source, rather than trying to develop structural treatment works for treating the highway runoff.

Introduction

The approach that is typically used to assess the "water quality impacts" from highway, street and urban area stormwater runoff (HSUA) is to monitor stormwater runoff by collecting a few samples of runoff at the edge of the drainage area from two to three storms per year and analyzing these samples for a suite of conventional potential pollutants, such as the heavy metals, petroleum hydrocarbons, PAHs, nutrients - N and P, total solids, suspended solids, enteric pathogenic organism indicators, etc. The results from these analyses are compared to US EPA (1987) water quality criteria/standards that have been established by regulatory agencies for the runoff receiving waters. If an exceedance of a water quality standard is found in the receiving waters, then the waterbody is said to be "impaired," and efforts are made to control the chemical constituents and pathogenic organism indicators, such as fecal coliforms, in the HSUA stormwater runoff through the use of BMPs to the maximum extent practicable. Traditionally, detention basins, grassy swales and other vegetative areas, oil-water separators and other structural BMPs are used to "treat" HSUA stormwater runoff. However, there is growing recognition that the traditional approach for assessing water quality impacts of chemical constituents in HSUA stormwater runoff is not technically valid and can lead to waste of public and private funds pursuing control of chemical constituents that ultimately have no impact on the designated beneficial uses of the receiving waters.

Problems with Current Regulatory Approaches

It has been known since the 1960s that many of the chemical constituents in stormwater runoff from urban areas are in particulate, non-available, non-toxic forms. Until recently, the development of BMPs for HSUA stormwater runoff focused on hydraulic considerations in the design of detention basins, etc. and failed to properly consider the aquatic chemistry and aquatic toxicology of chemical constituents in HSUA stormwater runoff as they relate to actual water quality issues of concern to the public. Further, the managers of traditional stormwater runoff water quality management programs often incorrectly assumed that the exceedance of a water quality standard in the runoff represented a significant impairment of the designated beneficial uses of the receiving waters for the runoff.

Those familiar with how US EPA water quality criteria and state standards based on these criteria were developed have known since the early 1970s that these criteria and standards are based on worst-case or near worst-case assessment of the potential impacts of chemical constituents on aquatic life-related beneficial uses of waterbodies. They also know that frequent substantial exceedances of water quality standards caused by HSUA stormwater runoff can occur without adversely affecting the aquatic life-related beneficial uses of a waterbody. As discussed by Jones-Lee and Lee (1994), Lee and Jones (1991a) and Lee and Jones-Lee (1993a, 1994a, 1995a,b,c,d), as well as in references contained therein, this arises from the situation that many of the constituents of greatest concern in HSUA stormwater runoff, such as heavy metals, are in particulate, non-toxic forms.

A second critical factor causing the exceedance of water quality standards in stormwater runoff to not necessarily represent an impairment of water quality is the short-term, episodic nature of runoff events compared to the aquatic organism exposure conditions that were used to develop the water quality criteria/standards. Aquatic organisms can be exposed to greatly elevated concentrations of toxic - available forms of constituents for short periods of time without adverse impacts. Typically, the criteria development approach involved exposures of organisms lasting several days to several weeks or more. In a typical HSUA stormwater runoff situation, toxic - available forms would normally be rapidly diluted in the receiving waters below concentrations adverse to aquatic life.

Complications Due to US EPA Independent Applicability Policy

Beginning in the early 1980s, the US EPA adopted implementation approaches for the Agency's water quality criteria and state standards which focused on total chemical constituents. Further, the Agency adopted the Independent Applicability Policy which required that numeric, chemically-based water quality standards had to be met in the receiving waters for wastewater discharges independent of whether the chemical constituents were in toxic - available forms (Lee and Jones-Lee, 1995e,f).

This Independent Applicability Policy has led to highly unreliable reporting of the water quality impacts of chemical constituents in HSUA stormwater runoff (Lee and Jones-Lee, 1996a). The US EPA and the states are required by Section 305(b) of the Clean Water Act to submit biennial reports on the quality of the nation's waters as part of the National Water Quality Inventory. These reports are submitted to Congress and provide the basis for establishing priorities for Congressional action on water pollution control programs. The most recent of these reports (US EPA, 1995a,b) follows the approach that was adopted by the US EPA several years ago of instructing states to report as impaired waterbodies any waterbody in which the concentrations of constituents exceed water quality criteria/standards in the region where the runoff enters the waterbody.

Lee and Jones-Lee (1996a) have discussed the technically invalid approaches that have been used by the US EPA in its National Water Quality Inventory for assessing the water quality significance of HSUA stormwater runoff. Every two years the US EPA's Report to Congress ranks "Storm Sewers/Urban Runoff" (*"Runoff from impervious surfaces including streets, parking lots, buildings, lawns, and other paved areas."*) as one of the leading causes of water quality impairment in the US. This ranking, however, is artificially high due to the use of exceedances of water quality criteria/standards as a basis for determining "impaired" waterbodies due to urban and highway runoff. The Agency through its biennial reports to Congress on the quality of the nation's waters has significantly overpresented the severity of the problem to Congress about the significance of HSUA stormwater runoff-associated constituents as a cause of water quality impairment in the nation's waters. This is especially true for any waterbodies which are ranked as "impaired" based on total concentrations of heavy metals rather than dissolved metals. As discussed herein, HSUA runoff contains elevated concentrations of particulate forms of heavy metals which do not impair the quality of receiving waters for the runoff.

The basic problem with the US EPA's National Water Quality Inventory is the same problem that occurred with those who have been developing traditional structural BMPs for HSUA stormwater runoff where it is assumed that any exceedance of a water quality standard in the runoff represented a significant impairment of the designated beneficial uses of the waterbody receiving the runoff. While exceedances of water quality standards in HSUA stormwater runoff waters are common, the impairment of the designated beneficial uses of a waterbody associated with these exceedances (real water pollution) is rare. For aquatic life-related beneficial uses the numbers, types and characteristics of desirable organisms in the receiving waters for the HSUA stormwater runoff must be significantly impaired before there is a real water quality problem associated with the exceedance of these standards. Such impairments are not being found in the studies of receiving waters for stormwater runoff from highways. The failure to focus on real water quality use impairments has led to significant over-regulation of chemical constituents in point and non-point source discharges.

Over-Regulation of Heavy Metals

One example of over-regulation resulting from a failure to focus on actual use impairment is the determination that a water quality use impairment exists when the total concentrations of heavy metals in runoff waters result in an exceedance of a water quality standard at the point which the heavy metals enter the receiving waters for the runoff. This problem has been compounded by lack of focus of regulatory programs on the appropriate forms of heavy metals.

It has been known since the late 1960s that particulate forms of heavy metals are non-toxic and non-available (NAS/NAE 1973). However, in the 1980s the US EPA's implementation of heavy metal criteria and state standards based on total heavy metals resulted in many states failing to adopt water quality standards for heavy metals. This eventually led Congress to adopt a National Toxics Rule which required that all states adopt water quality standards for heavy metals and other potentially toxic constituents.

The significant over-regulation that is occurring under the implementation of the National Toxics Rule has recently led the US EPA to change its approach to the regulation of heavy metals by focusing on toxic - available forms rather than total concentrations. The US EPA announced this approach as its official policy for implementation of the National Toxics Rule in the May 4, 1995 Federal Register (US EPA, 1995c). As a result, highway runoff BMPs, such as detention basins, which focus on removing particulate forms of heavy metals are now officially recognized as being technically invalid approaches (Lee and Jones-Lee, 1995g).

The US EPA's recent adoption of regulatory approaches based on dissolved forms of metals does not represent a new understanding of these issues. This was essentially the approach that was recommended by the National Academies of Science and Engineering in their Blue Book of Water Quality Criteria (NAS/NAE, 1973). It is also now beginning to be understood that even regulating dissolved forms of heavy metals represents over-regulation for many types of discharges due to the fact that many of the so-called dissolved forms are non-toxic and non-available as a result of the metals being present as complexes or colloids.

Heavy metals are not the only constituents which are being over-regulated; the same problem occurs with many organics, nutrients, etc. In general, regulating chemical constituents based on total concentrations is not an efficient approach to the problem and tends to divert or otherwise consume capital needed for the investigation and control of actual beneficial use impairments in receiving waters.

Control of Pollution vs. Achieving Standards

In 1990, the US EPA as part of adopting the national urban stormwater quality management program (US EPA, 1990a), recognized that significant over-regulation could occur if NPDES-permitted HSUA stormwater runoff was required to meet water quality standards at the point of discharge into the receiving waters. The Agency, in adopting the national urban stormwater management program, established the requirement that NPDES-permitted stormwater dischargers must control pollution caused by the discharges to the maximum extent practicable using BMPs. The Agency did not define what was meant by "maximum extent practicable" nor did it establish required BMPs. It did, however, define "pollution" as an impairment of the designated beneficial uses of the receiving waters for the permitted stormwater runoff.

Koorse (1995) has reviewed from a legal perspective the development of the regulatory background of the US EPA's Final Rule governing the regulation of stormwater runoff water quality from industrial and urban areas. He points out that there has been considerable confusion on how best to manage the water quality impacts of stormwater runoff-associated constituents.

At this time there is no requirement that HSUA stormwater runoff be treated to achieve water quality standards in the runoff waters. Further, in California the inappropriateness of requiring NPDES-permitted HSUA stormwater runoff to meet water quality standards (objectives) in the receiving waters was recognized by the Water Resources Control Board when a 10-year exemption from meeting these standards/objectives was granted to all NPDES-permitted HSUA stormwater runoff dischargers in April 1991. While that exemption no longer exists because of the court decision voiding the April 1991 objectives and the associated Inland Surface Water Plan and Enclosed Bays and Estuaries Plans, it is expected that with the re-promulgation of these plans, which is currently underway, this exemption will again be adopted.

In addition, the United States House of Representatives, as part of reauthorization of the Clean Water Act, proposes to allow a 15-year period of exemption from meeting water quality standards in permitted urban stormwater discharges. These proposed exemptions are based on the recognition that the application to stormwater discharges of the current water quality criteria/standards significantly over-regulates HSUA stormwater runoff. In an effort to correct this problem, the currently proposed Clean Water Act revisions provide $100 million to support US EPA research designed to develop appropriate wet weather criteria/standards that would be specifically designed to regulate HSUA stormwater runoff without significant over-regulation of permitted discharges.

Water Quality Impacts of Stormwater Runoff

Studies on Highway Runoff Impacts

Korbriger (1984a,b), Korbriger and Gupta (1984) and Korbriger and Geinopolos (1984) conducted studies for the Federal Highway Administration on the characteristics of highway runoff. While these studies are often cited as sources of information on the potential pollutional impacts of highway runoff, a review of the details of these studies shows that they did not distinguish between chemical constituents in highway runoff and those constituents which impair the designated beneficial uses of the receiving waters for the runoff. This was a significant deficiency in these studies in that while elevated concentrations of chemical constituents were found in the runoff, the studies did not include any evaluation of whether these constituents were present in toxic - available forms and whether the elevated concentrations of the constituents in highway runoff relative to US EPA water quality criteria and state standards occurred for a sufficient period of time in the receiving waters to be adverse to the beneficial uses of these waters.

Kerri *et al.* (1985) and Racin *et al.* (1982) have also presented information on pollutant loads from highway runoff. These studies also did not distinguish between chemical constituents in highway runoff and pollutants, i.e. those materials that impair the beneficial uses of a waterbody.

Driscoll *et al.* (1990) reported on "pollutant loadings and impacts of highway stormwater runoff." A review of this report shows that while information is provided on constituent concentrations in highway runoff, the authors failed to evaluate whether the chemical constituents in the highway runoff were in toxic-available chemical forms and would be present for sufficient duration at "excessive" concentrations in the receiving waters to be adverse to aquatic life and other beneficial uses of the receiving waters for the runoff.

Driscoll *et al.* utilized the event mean concentration of a highway stormwater runoff event to "characterize" the potential impacts of the chemical constituents in highway stormwater runoff. While this approach reduces the data obtained in monitoring a particular or series of runoff events to a single value, it is a highly unreliable approach for assessing water quality impacts of highway and other area stormwater runoff. As discussed by Lee *et al.* (1982) and Lee and Jones-Lee (1995a) aquatic organisms respond to concentration of toxic - available form duration of exposure relationships. The event mean concentration approach does not adequately or reliably incorporate key information that has to be available to determine whether excessive concentrations of heavy metals or organics, etc. in highway runoff relative to water quality standards are adverse to aquatic life-related beneficial uses.

The event mean concentration in addition to failing to focus on toxic - available forms also fails to properly consider the duration of exposure impact relationships that must be incorporated into a reliable analysis of the impacts of stormwater runoff. Overall, the studies of Driscoll *et al.*do not provide the information needed to reliably assess whether the runoff of chemical constituents from highways represents a potentially adverse impact on the beneficial uses of the receiving water for the runoff.

Stenstrom and Strecker (1993a,b) used similar approaches to those of Driscoll *et al.* to estimate the so-called chemical pollutant loads to Santa Monica Bay from highway and street runoff from the Santa Monica Bay watershed. While the results of their investigations were presented as "pollutant" loads, in fact, they should have been labeled "chemical constituent" loads. According to tradition, technical validity and the US EPA's (1990a) stormwater quality management regulations, a pollutant is a constituent that impairs the beneficial uses of the waterbody. It is not possible to use either event mean concentrations or total mass of constituents from highway or street runoff to estimate the pollution that will occur in the receiving waters for the runoff. The inappropriateness of the Santa Monica Bay Restoration Project in developing the management plan for the restoration program in which the Stenstrom and Strecker (1993a,b) results are used as a basis for formulating best management practices has been discussed by Lee (1995). The implementation of this proposed plan involves the development of over $40 million in structural BMPs to primarily control heavy metals in HSUA runoff. This is being done without finding a real water quality use impairment in Santa Monica Bay that is caused by these heavy metals. As discussed by Lee (1995), there is obvious need to find a real water quality problem in Santa Monica Bay first and then develop a restoration plan to control this problem in a technically valid, cost-effective manner.

Al-Kazily *et al.* (1995) have prepared a report for Caltrans concerned with a review of stormwater runoff monitoring from Caltrans highways. In a discussion of the conventional stormwater monitoring approach, Al-Kazily *et al.* state,

"The disadvantage of this approach to the storm water runoff management program is that, lacking good information about the potential problems in a specific receiving water, the problem is presumed to exist and money may be spent unnecessarily."

They further state,

"Careful planning is important to ensure that known problems are tackled first while efforts are made to determine whether actual problems exist at other locations. The discharger is encouraged to prioritize efforts in both of these areas."

In using stormwater monitoring to assess the impact of receiving waters, Al-Kazily *et al.* state,

"Identification of adverse impacts on receiving waters should be a cooperative effort between the dischargers in each watershed; however, coordination with municipal agency monitoring is needed."

The Al-Kazily *et al.* (1995) report to Caltrans supports the development of an evaluation monitoring approach of the type being developed for the highway in which real water quality use impairments are found and then site-specific source control measures are developed to control the real use impairments associated with highway runoff.

It is now being found that where there is toxicity in urban stormwater and highway runoff, this toxicity appears to be due to agriculture and/or urban use of pesticides, such as diazinon. The heavy metals and other organics in HSUA stormwater runoff are not being found to be toxic to aquatic life. In some cases, such as in the Sacramento, California area, the spraying of orchards with diazinon in the winter causes HSUA stormwater runoff to be toxic to aquatic life at considerable distances from the point of application - spraying due to airborne transport of the diazinon. Diazinon is an organophosphorus pesticide that is highly toxic to zooplankton. Studies by Connor (1995), Domagaiski (1995), Kuivila (1993), USGS (1993), Kuivila and Foe (1995), MacCoy *et al.* (1995), and Foe (1995a,b) have shown that orchard or other area-derived diazinon causes runoff waters from the area to be toxic for several weeks for considerable distances downstream in the Sacramento and San Joaquin Rivers and in the Sacramento - San Joaquin River Delta system.

It appears now that an appropriate BMP to control diazinon toxicity in the highway runoff is through source control. Since diazinon is dissolved, it is obvious that the conventional highway stormwater BMPs, such as detention basins, will have no effect on the diazinon-caused aquatic life toxicity since diazinon would not be removed in detention basins or filters. Those who manufacture, sell or use diazinon and other pesticides that become part of HSUA stormwater runoff, as well as runoff from the orchards and other agricultural or rural lands, must be able to control the use so that there is no significant toxicity to aquatic life in the receiving waters for HSUA stormwater runoff. Highly specific source control BMPs of this type will likely be the primary mechanism by which potentially significant water quality problems can be effectively addressed and controlled for a variety of constituents that are found to cause water quality use impairments from highway runoff.

Recent Findings Regarding Urban Stormwater Runoff Impacts

In 1991 the American Society of Civil Engineers Urban Water Resources Research Council sponsored the Engineering Foundation Stormwater Conference. This was part of a series of conferences that have been held every couple of years devoted to urban runoff issues. The 1991 conference was devoted to an assessment of stormwater runoff impacts on receiving waters (Herricks, 1995). A review of these proceedings shows that there are few documented cases where the chemical constituents in stormwater runoff from highways and urban areas have been found to be significantly adverse to the designated beneficial uses of the receiving waters for this runoff.

Pitt (1995) in these conference proceedings has presented a review of some of the literature on the biological effects of urban stormwater runoff. Most of the "effects" are based on chemical concentrations and are not real biological effects. These "effects" fail to consider toxic - available forms of chemical constituents in making the evaluation of the true impact of the urban stormwater runoff-associated constituents.

Herricks, editor of the proceedings, states,

"...best management practices need to be holistic, and that any control strategy needs to be a reasoned application based on scientific understanding, not rule of thumb practice."

Davies (1995) presented a review of many of the issues that need to be addressed in evaluating and controlling non-point source runoff impacts. He states, *"It is generally agreed that NPS* [nonpoint source] *problems are unique and complex, and they will not be resolved as easily as the relatively simple treatment and standard compliance approaches used in the PS* [point source] *program. NPS programs will require development and application of innovative and imaginative control strategies, and the program will cost much more than the PS program."*

The general conclusion from the conference proceedings is that there has been far too much use of rule of thumb - standard practice approaches used in stormwater quality evaluation and management. Instead, there is need to focus on finding real water quality problems and solving them in a technically valid, cost-effective manner.

In August 1994, the Engineering Foundation held a stormwater NPDES-related monitoring needs conference which focused on the current state of knowledge related to the monitoring of HSUA stormwater runoff for water quality impacts. Urbanos and Torno (1994), in an overview summary of the conference, discussed that at this time very little is known about the water quality impacts of urban stormwater runoff. They state,

"If we are to acquire this understanding, we must stop wasting monitoring resources on the `laundry list' type of monitoring encouraged or required by our current regulations. We must instead move towards well-designed and adequately funded national and regional scientific study programs and research efforts."

The logical, common-sense, technically valid and cost-effective approach for managing real water quality use impairments (pollution) caused by HSUA stormwater runoff is to first find a real water quality problem in the receiving waters for the runoff, determine the specific cause of this problem and develop site-specific source control methods to control the problem to the maximum extent practicable. This is the approach imbedded within the evaluation monitoring program that is proposed as the basis for managing water quality impacts due to stormwater runoff from the highway.

Evolving Changes in Stormwater Management and Monitoring

The California State Water Resources Control Board ard/American Public Works Association Stormwater Quality Task Force has recently initiated an effort to review the appropriateness of current stormwater quality monitoring and management approaches. It has been concluded that current monitoring approaches focusing on measuring chemical constituents in stormwater runoff provide little useful information that can be used to develop technically valid, cost-effective BMPs. The Task Force's Stormwater Monitoring Committee has concluded that there is need to shift the emphasis of the monitoring programs from runoff waters to the receiving waters in which efforts would be devoted to defining real water quality use impairments associated with the constituents in the runoff waters.

Recently, the US EPA (1995d) announced an "Advanced Notice of Proposed Rulemaking on the Water Quality Standards Regulation." The purpose of this Rulemaking is to re-examine the approach that was adopted over 10 years ago for developing and implementing water quality criteria and standards. One of the areas that will be specifically addressed as part of this Rulemaking is the regulation of urban and highway stormwater runoff. The Agency has indicated that it is considering developing wet weather criteria/standards that would address the specific problems associated with trying to use the current national water quality criteria as a basis for developing a regulatory approach for managing stormwater runoff quality.

Another area that the Agency indicated that it will address as part of the proposed Rulemaking is the Independent Applicability Policy. Consideration is being given to changing this Policy so that exceedances of chemically-based water quality criteria and standards can be over-ridden by biological effects-based criteria/standards and assessments. Of particular concern is the use of ambient water toxicity tests and/or receiving water aquatic organism assemblage information to determine whether the chemical criteria are over-estimating the impacts of chemical constituents in the stormwater runoff on the beneficial uses of the waterbody.

In summary, the current approach for regulating stormwater HSUA runoff is changing. The approach of measuring concentrations of constituents in runoff waters and then assuming that any exceedance of water quality criteria/standards represents an impairment of a designated beneficial use is being replaced by a site-specific, waterbody assessment of use impairment approach in which the focus of stormwater runoff water quality BMP development is devoted to controlling real water quality use impairments of significance to the public.

Development of the Evaluation Monitoring Program

Presented below is a summary of the key components of evaluation monitoring that should be used to determine whether HSUA stormwater runoff is causing a significant adverse impact on receiving water water quality and, therefore, there is need for a BMP to control HSUA stormwater runoff characteristics.

Aquatic Life Toxicity

Aquatic life toxicity is one of the areas of concern in evaluating the impact of HSUA stormwater runoff on receiving water quality. HSUA stormwater runoff contains concentrations of heavy metals and other constituents above those levels that are potentially toxic to aquatic life under worst-case conditions of 100% available forms and extended duration's of exposure. In order to evaluate whether the potentially toxic regulated chemicals which occur in runoff at concentrations above water quality criteria/standards are toxic in the receiving waters and to evaluate whether there are unregulated chemicals such as diazinon and other pesticides used in agricultural crops and in urban areas that can cause toxicity in receiving waters for HSUA stormwater runoff, it is necessary to directly measure toxicity in the receiving waters.

Davies (1995) in a discussion of "Detecting Toxicity Problems in Urban Runoff" states, *"Outside of a major fish kill in a receiving water stream, how would toxicity problems be detected? Attempts to analyze water from these systems for all possible toxicants would be extremely difficult and very expensive. Biomonitoring methods should first be used to determine if toxicity exists using, for example, the water flea* (Ceriodaphnia dubia) *as a test organism. Screening tests for acute toxicity can be conducted in two days, or a more sensitive life cycle test in seven days. Once toxicity has been established in a particular drainage system, biomonitoring can be used to locate and identify potential sources. With knowledge of types of activities or industries in the defined area, the kinds of potential toxicants can be narrowed and selective analyses performed. Once a toxicant(s) has been identified and attributed to a particular source, control can be implemented through normal regulatory channels."*

Recently, de Vlaming (1995a,b) of the California Water Resources Control Board staff has conducted a comprehensive review of the reliability of toxicity testing using acute or chronic tests in predicting water quality use impairments that are manifested as impaired aquatic organism populations. There are many situations where chemical composition of waters in which potentially toxic elements exceed US EPA water quality criteria do not reliably predict the water quality impacts in the receiving water for a wastewater discharge. This situation has led to the development of Whole Effluent Toxicity (WET) tests. de Vlaming reported that toxicity measurements on an effluent have been found to predict biological community impacts in the receiving waters for the effluent about 70% of the time. The reliability of the toxicity tests for estimating in-stream biological responses was improved when toxicity tests were conducted with ambient water and when the exposure conditions that organisms would experience in the ambient waters were duplicated in the toxicity test. Overall, de Vlaming concludes that the

"Available literature yields a compelling, weight of evidence, demonstration that the WET, and other indicator species, toxicity test results are accurate qualitative predictors of instream biological community responses."

de Vlaming also indicated that in August 1995 the Society for Environmental Toxicology and Chemistry held a "Pellston" workshop devoted to the reliability of effluent toxicity tests in predicting water quality impacts in receiving waters. The participants in the workshop were experts in this field. While the proceedings of this workshop will not be published until the summer 1996, according to Denton (1995), the workshop participants came to the same conclusion as de Vlaming on the reliability of toxicity tests in predicting biological community impacts.

de Vlaming's review provides considerable support for the validity of the evaluation monitoring assessment of toxicity in which multiple species short-term chronic toxicity tests are used on ambient waters in which the duration of exposure and dilutions that occur in the receiving waters for stormwater runoff are simulated in the test conditions. It can be expected that if toxicity that persists in the receiving waters for stormwater runoff is found under these conditions, that there would be adverse impacts on the biological populations in these waters. Under these conditions the specific cause of this toxicity should be identified through a TIE. Further, in accord with current regulatory requirements, if the cause of toxicity is urban area or highway runoff, then BMPs need to be implemented to control the toxicity to the maximum extent practicable.

The evaluation monitoring program approach focuses on assessing toxicity in the receiving waters for the stormwater runoff. Rather than measuring heavy metals in runoff which are of importance because of their potential aquatic life toxicity in the receiving waters, toxicity in the receiving waters is measured before, during and after a stormwater runoff event. This approach is in accord with Davies' (1995) previously discussed recommendation for assessing the potential toxicity associated with non-point source runoff.

Measurement of toxicity in the runoff waters does not necessarily translate into significant toxicity in the receiving waters for the runoff. Caution should be exercised in assuming that the toxicity measured in runoff waters results in significant toxicity in the receiving waters for the runoff that leads to an impairment of the designated beneficial uses. The US EPA (1991) in the Agency guidance for implementing the WET test results states,

"The regulatory authority must carefully look at the test protocols and all the data collected to determine if the facility is actually contributing to toxicity in the ambient water."

The issue is not whether the HSUA stormwater runoff is toxic at the point of discharge; the issue with respect to beneficial use impairment of the receiving waters for the stormwater runoff is whether there is sufficient aquatic life toxicity for a duration and areal extent to be significantly toxic to aquatic life in the receiving water water column. Lee and Jones (1991a) discussed the approach that should be followed in evaluating the significance of HSUA stormwater runoff toxicity. As they discussed, toxicity measurements should be made over time within and near the discharge plume. These toxicity tests should mimic the duration of exposure and concentration time profile for aquatic organisms under the influence of the HSUA stormwater discharge.

Figure 1 illustrates a general sampling regime for stormwater discharges into rivers, lakes, bays and nearshore marine waters. The sampling program for a particular location should be developed based on information derived from following drogues released at the point of stormwater discharge that move with the ambient water/discharge water mixture. By sampling at various times along the drogue path, it is possible to estimate the rate of dilution that occurs in the ambient waters and therefore the times that should be used to estimate the duration of exposure of the test organisms in the toxicity tests to various concentrations of the stormwater discharge.

Since it is possible that the receiving waters for the runoff may also be toxic from other causes than the runoff of concern, it is important to determine the toxicity in the runoff water discharge plume and outside of it. Under these conditions, an assessment should be made of whether the runoff contributes sufficient toxicity for sufficient duration and areal extent in the receiving waters to be considered of significance in impairing the designated beneficial uses of the receiving waters. It is also important to understand how the toxic response in the toxicity testing procedures used compares to the toxic responses possible in the receiving waters for the runoff in evaluating potential toxicity found in runoff waters.

The focus of the toxicity measurements should be based on short-term, chronic testing using fish larvae and zooplankton. The US EPA has developed guidance manuals for freshwater and marine systems (US EPA 1994a,b, 1995e). Lethality, impairment of reproduction, and growth should be used as toxicity end points in the toxicity testing. Because of the inability to reliably interpret algal toxicity data, it is recommended that algal toxicity tests not be used for this purpose (Lee and Jones-Lee, 1994b).

Measurements should be made of the receiving waters' toxicity for selected storms each year representing the seasons in order to determine whether the HSUA stormwater runoff contributes significant toxicity to the receiving waters at any time during the year. There can be significant seasonal toxicity in HSUA stormwater runoff such as that found in the runoff waters in the Sacramento, California area where diazinon is used in the winter as a dormant spray in orchards and is carried for considerable distances through the air and causes toxicity in urban and highway stormwater runoff.

If the evaluation monitoring toxicity assessment shows that there is potentially significant toxicity in the receiving waters for the runoff, then TIE studies should be conducted to determine the specific source and cause of the toxicity. The US EPA has provided several guidance manuals on how to conduct TIE investigations (US EPA, 1989a,b,c,d, and Fava, *et al.*, 1989). These approaches have been used by a number of investigators to show that diazinon is a widespread cause of aquatic life toxicity in receiving waters for urban stormwater runoff.

Toxicity does not have to be present in all HSUA stormwater runoff to be adverse to receiving water water quality. Seasonal, widespread toxicity such as that which occurs associated with diazinon's use in orchards in the winter should be considered a significant adverse impact on receiving water water quality and require the development of BMPs to control this toxicity.

If no toxicity is found in the receiving waters or if the extent, duration and intensity of toxicity in the receiving waters is not sufficient to be significantly adverse to the numbers, types and characteristics of desirable aquatic life in the receiving waters for the stormwater runoff, it can be concluded that at the time of study, that all of the potentially toxic heavy metals, organics, etc., in the HSUA stormwater runoff as well as from all other sources, are non-toxic. Therefore, there would be no need for any additional BMPs to control potentially toxic chemicals in HSUA stormwater runoff as well as from all other sources of constituents for the waterbody.

If, however, potentially significant toxicity is found, then an assessment of the cause of this toxicity in the HSUA stormwater runoff should be conducted. Once the cause is known, the specific source(s) of the constituents responsible for the toxicity can be ascertained and potentially controlled at the source. An example of this type of situation has occurred where urban stormwater dischargers in many locations in the US have found that diazinon is a cause of aquatic life toxicity in the discharge waters. This toxicity occurs at various times of the year and is not related to the situation described above of the use of diazinon as a dormant spray in orchards in the winter in the Sacramento, California area.

The general toxicity in urban runoff being found that is caused by diazinon at various times of the year at many locations is due to its use on homes for structural treatment, control of insects in lawns, etc. At this time, the significance of this home use diazinon-caused HSUA stormwater runoff toxicity in adversely impacting receiving water water quality is not known since the studies necessary to define the degree, extent and duration of it in the receiving waters have not, to the knowledge of the authors, been conducted. There could be situations where this toxicity is rapidly lost in the receiving waters and is of no consequence in causing beneficial use impairment of these waters. In other situations, however, sufficient toxicity could persist for sufficient periods of time to be adverse to the beneficial uses of the receiving waters. Of particular concern would be small perennial urban streams, which maintain a desirable aquatic life habitat. Such streams could receive sufficient urban runoff derived toxicity to be adverse to aquatic life in the stream. It is this type of situation for which there is need to develop a BMP to control the diazinon or, for that matter, any other cause of toxicity in the receiving waters for HSUA stormwater runoff.

Bioaccumulation

Certain chemicals, such as chlorinated hydrocarbon pesticides, PCBs, dioxins and mercury, which are known or suspected to cause cancer in man and/or are neurotoxins, tend to bioaccumulate in edible aquatic organism tissue to a sufficient extent to cause regulatory agencies to issue a health advisory for the consumption of that organism. While, ordinarily, today the presence of large amounts of these chemicals in HSUA stormwater runoff is rare, it is important as part of any evaluation monitoring program to determine whether excessive bioaccumulation of chemical constituents that could lead to health advisories in the receiving waters for the runoff is occurring.

Also of concern is the bioaccumulation of chemicals in aquatic organisms which represents a significant threat to higher trophic level organisms, such as fish-eating birds and mammals, to endanger the health and reproduction of these organisms. The US EPA (1993a) has issued guidance on the development of wildlife criteria which is designed to protect wildlife from the consumption of aquatic life that contain excessive concentrations of hazardous chemicals. While this guidance was developed for the US - Canadian Great Lakes, it has applicability throughout the US.

The traditional approach for assessing bioaccumulation in HSUA stormwater runoff is to measure the concentration in runoff waters and then attempt to extrapolate from these concentrations to the concentrations that could be found in aquatic organism tissue. However, it is well-known that this approach is not reliable. The accumulation of many organics and mercury in aquatic organism tissue is basically a partitioning process in which the concentrations in the water or sediments equilibrate through partitioning with aquatic organisms. Typically, the factors controlling the uptake are variable from site to site and are controlled primarily by the amounts and types of carbon compounds in the water, sediments and the aquatic organism tissue fat content.

Unlike toxicity, excessive bioaccumulation is based on excessive concentrations of a specific chemical. Therefore, the chemical responsible for the health advisory is known. However, chemical constituents exist in aquatic systems in a variety of chemical forms, only some of which can bioaccumulate in aquatic organism tissue to excessive levels. It is unreliable to assume that because an elevated concentration of a chemical constituent is found in aquatic organism tissue upon exposure to a particular source of the chemical, that that source will be responsible for causing or contributing to excessive bioaccumulation in aquatic organisms of concern to the public because of their use as food or because they are important food for higher trophic level birds or mammals.

While the US EPA and Corps of Engineers (US EPA/COE, 1991,1994) have developed some standardized equations for estimating bioaccumulation based on concentrations in water, these equations are not reliable for predicting uptake by organisms in various types of waterbodies. At this time, the only way to reliably assess whether constituents in HSUA stormwater runoff bioaccumulate in aquatic organisms to excessive levels is to measure the concentrations in the HSUA stormwater runoff-impacted receiving water organism tissue. If excessive concentrations are found relative to a properly developed "standard," then site-specific evaluations have to be made to determine whether the HSUA stormwater runoff is the source of the chemical of concern.

There is considerable confusion, and a number of inappropriate approaches are being used today by regulatory agencies and others in assessing whether excessive concentrations of a chemical are present in aquatic life tissue. It is important not to assume that an elevated concentration in organism tissue causes an adverse impact to that organism or higher trophic level organisms unless the necessary studies have been conducted which show that the accumulation of the chemical in the organism tissue is, in fact, adverse to the organism or higher trophic level organism. For human health, this would represent the development of a health advisory on the consumption of the organism edible tissue.

Some regulatory agencies, in an attempt to try to find some way to use chemical data associated with analysis of aquatic organism tissue, have contrived a variety of approaches which superficially appear to have some validity in the interpretation of bioaccumulation data. Concentrations above the mean or median concentration normally found in organism tissue, the so-called National Academy of Science values used only in California and a few other jurisdictions, are not valid for assessing the beneficial use impairment that a tissue residue represents.

Over the years, considerable attention has been given to attempting to evaluate the water quality and public health significance of tissue residues in various forms of aquatic life.

After careful review, it is generally concluded that there are few chemicals where reliable information is available on what constitutes an excessive concentration of a chemical in aquatic organism tissue. Aquatic organisms and many mammals, including man, are known to accumulate a variety of fat-soluble chemicals in their tissue without any significant adverse impact on the organism and man. Therefore, the valid approach available today for interpreting bioaccumulation data is a Food and Drug Administration (FDA) Action Level or a US EPA or other agency risk-based human health advisory. Further, for human health advisories, it is important to focus bioaccumulation evaluation on edible tissue of organisms that are actually used as food and not on zooplankton, worms, or some lower trophic level organisms which are not used as food covered by the human health advisory.

The US EPA has recently developed a series of manuals on assessing excessive ioaccumulation of chemicals in aquatic life tissue (US EPA 1992a, 1993b, 1994c, 1995f). The US EPA has developed a risk-based approach for determining the allowable tissue levels of potential carcinogens and mercury that will protect the public who use these organisms as food. These guidance manuals should be consulted for further information on the evaluation of excessive concentrations of chemicals in edible aquatic organism tissue.

If excessive concentrations above health advisories or US EPA wildlife criteria based on tissue concentrations are not found in the receiving waters for appropriately tested aquatic organisms, then there is no need for further monitoring of chemical constituents in HSUA stormwater runoff for those chemicals that are of concern because of their potential to bioaccumulate to excessive levels. If, however, excessive accumulations of potentially hazardous chemicals are found, site-specific studies will likely require a combination of laboratory uptake studies which simulate receiving water conditions and field studies using caged organisms in the areas where HSUA stormwater runoff could likely be responsible for the excessive bioaccumulation. The US EPA/COE (1991,1994) provide information on conducting laboratory based bioaccumulation studies. Newbry and Lee (1984) have provided information on inexpensive cages that can be used for conducting such studies. It will be important to conduct these studies both within and outside but near the area of potential influence for the highway stormwater runoff to ascertain whether this runoff is a significant contributor to excessive aquatic organism tissue concentrations.

As with toxicity, site-specific BMPs can be developed to control those constituents in HSUA stormwater runoff which lead to the excessive bioaccumulation in aquatic organisms in the receiving water for the runoff.

Adverse Impacts of Sediment-Associated Constituents

It is possible that chemical constituents in HSUA stormwater runoff could accumulate in receiving water sediments and thereby cause a significant use impairment of these waters through sediment toxicity and/or serving as a source of chemicals that lead to excessive bioaccumulation in aquatic organism tissue. The accumulation of chemicals in sediments can be due to either particulate forms of the constituent in the HSUA stormwater runoff or dissolved forms in the runoff which become particulate in the receiving waters through sorption, precipitation and/or bio-uptake by lower trophic level organisms, such as algae, which die, settle and become part of the sediments.

A variety of chemical reactions occur in aquatic sediments which detoxify heavy metals and other constituents, rendering them inert. It would be, indeed, rare that heavy metals and many other constituents in urban stormwater runoff from highways, streets and residential areas, as well as most commercial and industrial areas, would be toxic in aquatic sediments to a sufficient extent to impair the designated beneficial uses of the waters associated with the sediments.

It has been known for over 25 years that it is not possible to use heavy metal concentrations in sediments to reliably predict water quality problems associated with heavy metals, organics and other constituents. It is necessary to use biological effects-based evaluations of potential water quality impacts (toxicity and bioaccumulation) in order to determine if heavy metals or other constituents in sediments are significantly impairing the beneficial uses of a waterbody.

Since the mid-1970s, the US EPA and the Corps of Engineers (COE) have been regulating excessive concentrations of chemicals in sediments associated with navigational waterway dredging and dredged sediment disposal as they may impact the beneficial uses of the waterbody in which the disposal takes place. Based on the research that was done in the 1970s under COE's Dredged Material Research Program, the US EPA and the Corps of Engineers adopted an effects-based approach involving direct measurement of sediment toxicity and estimates of bioaccumulation. In 1991, the US EPA and the Corps of Engineers updated their Testing Manual for ocean disposal of contaminated sediments (US EPA/COE, 1991). The Agency and Corps are now updating their freshwater dredged sediment disposal manual based on similar approaches to those that have been used for nearly 20 years (US EPA/COE, 1994). US EPA (1992b, 1993c) has published additional information on sediment quality evaluation procedures. A discussion of the development and use of these procedures is provided by Lee and Jones (1992) and Lee and Jones-Lee (1994c).

Biological effects-based techniques are well-established to determine whether potentially toxic constituents that accumulate in sediments are adverse to the waterbody in which the sediments are located. As with water column effects, the evaluation monitoring program should be conducted to define real water quality use impairments associated with any accumulated runoff-derived constituents in the receiving water sediments. Lee and Jones-Lee (1993b, 1994c,d) have reviewed issues pertinent to evaluating the water quality significance of chemical constituents in aquatic sediments. As they discuss, both aquatic life toxicity to a suite of sensitive aquatic organisms and bioaccumulation in aquatic organism tissue of chemicals that are of potential concern to human health and wildlife, should be evaluated as part of a biological effects-based sediment quality evaluation. Selected chemical analysis of the sediment should be made for the regulated chemicals such as heavy metals, PAHs and ammonia as well as for the constituents in aquatic sediments that tend to detoxify - immobilize regulated chemicals (TOC, sulfides, etc.) as part of the TIE evaluation conducted to determine the cause of the toxicity.

Similar approaches to those developed by the US EPA and COE could readily be used to address the issue of whether chemical constituents in HSUA stormwater runoff are responsible for significantly adversely impacting the beneficial uses of the waterbody receiving the runoff through accumulation of dissolved and particulate constituents in the runoff in the receiving water sediments. Toxicity tests, field bioaccumulation studies, and benthic aquatic organism assemblages (numbers, types and characteristics) can be used in a non-numeric, best professional judgment, weight-of-evidence triad to determine whether aquatic sediments in the vicinity and downstream of an HSUA point of runoff are a significant contributor to the impairment of the designated beneficial uses of the receiving waters for the runoff. Further information on this approach is provided by Lee and Jones-Lee (1993b).

It is not necessary to know the specific cause of sediment toxicity in order to determine if a particular section of highway or other area is contributing to sediment toxicity. Toxicity tests can be used to trace the origin of toxicity to its source for those situations where the toxic form of the particulate constituent is derived from stormwater runoff.

It is possible to conduct a sediment-based TIE to determine the cause of the toxicity for those sediments that are found to have sufficient toxicity to impair the beneficial uses of the waterbody. Ankley *et al.* (1991) have developed guidance on conducting TIEs on aquatic sediments. The information developed from the TIE can then be used to develop a technically valid, cost-effective approach for implementing stormwater runoff BMPs.

It is important to not try to use chemically-based approaches such as Long and Morgan values, McDonald values and AETs, for assessing water quality impacts of sediment-associated constituents. Such approaches are highly unreliable (Lee and Jones-Lee, 1994d). Sediment water quality impacts should be based on biological effects-based assessments (Lee and Jones-Lee, 1993b).

If significant water quality use impairments are found associated with sediment-associated constituents derived from HSUA stormwater runoff sources, then site-specific BMPs focusing on source control can be developed which will specifically address the dissolved and/or particulate constituents in the runoff that are responsible for the sediment constituent-associated impairment of the waterbody's beneficial uses.

It is important to understand that finding toxicity in aquatic sediments should not be interpreted to mean that this toxicity is a significant cause of a beneficial use impairment for the waterbody in which the sediments are located. Many aquatic sediments are naturally toxic due primarily to the growth of algae and other aquatic plants in the waterbody, which upon death, accumulate in sediments and exert an oxygen demand which uses up all dissolved oxygen (DO). The low DO conditions in sediments lead to the accumulation of ammonia and hydrogen sulfide, both of which are highly toxic to aquatic life. While these conditions occur naturally, the activities of man in a waterbody's watershed can increase the amounts of aquatic plant nutrients contributed to a waterbody and therefore the toxicity of the sediments.

The natural toxicity of sediments due to low DO, NH_3 and H_2S is not necessarily a significant factor in adversely impacting the designated beneficial uses of waterbodies. Many waterbodies with highly toxic sediments have highly desirable aquatic life resources. At this time, there is a poor understanding of the coupling between sediment toxicity and the impairment of the designated beneficial uses of waterbodies. Work needs to be done to understand how the control of constituents in HSUA stormwater runoff which accumulate in receiving water sediments causing or contributing to sediment toxicity influences the beneficial uses of waterbodies. Until this work is done, there can be little justification for developing BMPs to control chemical constituents in HSUA stormwater runoff because they accumulate in aquatic sediments.

Excessive Fertilization-Eutrophication

The excessive fertilization of waterbodies is one of the major causes of water quality use impairment. This impairment is manifested primarily as an impact on the aesthetic quality of waters where excessive algal and waterweed growth impacts the use for recreational purposes. For domestic water supplies, excessive fertilization leads to a number of problems such as increased taste and odors, shortened filter runs and increased trihalomethane precursors. As discussed by Jones and Lee (1982, 1986) and Lee and Jones (1991b), while increasing the fertility of a waterbody results in an overall increased fish biomass, increased fertility generally results in a deteriorated quality of fish where less desirable, rough fish, such as carp, become predominate. Lee and Jones (1991a) and Lee and Jones-Lee (1996b) have discussed the importance of evaluating the potential significance of HSUA stormwater runoff-derived nutrient loads compared to other sources of nutrients for a waterbody. Rast and Lee (1983, 1984) have provided guidance on how this can be accomplished.

Per unit area, highway, street and urban areas tend to export more nitrogen and phosphorus per year than most agricultural - rural lands. An important exception occurs with dairies and some other animal husbandry activities. There are situations where urban street runoff has caused excessive fertilization of small urban lakes (Lee and Jones, 1980). Ordinarily, however, excessively fertile waterbodies near urban areas and highways obtain most of their nutrients from domestic wastewater sources, agricultural and rural land runoff, the atmosphere and from nitrogen compounds in groundwater that discharge to the waterbodies.

There are several important issues that need to be addressed in developing nutrient-based BMPs for HSUA stormwater runoff. One of these is the need to focus the nutrient control program on those forms of nutrients (N and P) that can stimulate algal growth in the receiving waters. For most freshwater systems, the nutrient control program must be focused on algal-available phosphorus and not total phosphorus. Similarly for those waterbodies in which nitrogen is the chemical controlling algal biomass that develops in the waterbody, the control programs must focus on available forms of nitrogen compounds. While for most fresh waterbodies, phosphorus is the element limiting algal biomass, there are situations, however, such as Lake Tahoe in California - Nevada, where nitrogen is the limiting element controlling algal growth. Under these conditions, it is the algal available nitrogen in the HSUA stormwater runoff relative to other sources of these nitrogen compounds that must be evaluated. Lee and Jones-Lee (1994e) have reviewed the Lake Tahoe nutrient (nitrogen) source situation where they have reported that the most significant source of nitrogen compounds (nitrate and ammonia) is the atmosphere through direct precipitation on the Lake's surface. As they discussed, BMPs directed toward controlling nitrogen from associated land runoff will not be effective in controlling the excessive fertilization of Lake Tahoe that is occurring today.

For marine waters, it is typically the algal available nitrogen that is the key constituent in controlling algal biomass in the receiving waters, although there may be situations where phosphorus can become an important element in controlling algal growth in nearshore marine waters. A site-specific evaluation of the relative significance of nitrogen vs. phosphorus in controlling excessive fertilization of a waterbody must be made in order to determine whether algal-available forms of the controlling element present in HSUA stormwater runoff are significant contributors to the excessive fertility of the waterbody.

Lee *et al.* (1980) have provided guidance on the determination of available forms of aquatic plant nutrients in runoff waters and sediments. Basically, for nitrogen it is the nitrate plus ammonia as N plus part of the organic nitrogen in the runoff waters that become available in the receiving waters to support algal growth. For phosphorus, it is the sum of the soluble orthophosphate plus about 20% of the particulate phosphorus that is available to support algal growth in HSUA runoff. Site-specific determinations of available N and P can be assessed through the use of algal bioassays.

Lee and Jones (1988a) have provided guidance on the approaches that can be used to determine whether nitrogen or phosphorus is the key limiting element in controlling algal biomass in a waterbody. As they point out, a number of the approaches that are used such as the ratios of N and P in the waterbody are not necessarily reliable and can readily lead to incorrect conclusions on the significance of nitrogen or phosphorus in controlling algal growth. It is important to ascertain whether the proposed limiting nutrient is, in fact, decreased to algal growth rate limiting concentrations during peak algal biomass. If it is found that during the peak of the algal bloom the algae still have available to them surplus amounts of available forms of nitrogen and phosphorus, then these elements are not limiting the algal biomass.

It is also important to consider the hydraulic/morphologic characteristics of the waterbody (flushing time) receiving the HSUA runoff at various times of the year. If it is found that any nutrients added to the waterbody during one time of the year are effectively flushed out before the period of the year when excessive algal growth occurs, then the nutrients contributed to the waters during the non-growth periods are not contributing to the eutrophication-related water quality problems.

Further, a distinction should be made between eutrophication-related water quality problems which are manifested as excessive growths of planktonic algae vs. the growths of attached algae, attached and floating macrophytes and emergent vegetation. With respect to the latter, at this time there is a poor understanding of nutrient load - concentrations eutrophication response relationships.

Jones and Lee (1982,1986) have provided guidance on how to evaluate the potential benefits of controlling phosphorus inputs to a certain degree on the eutrophication-related water quality of a waterbody. They recommend the use of the Vollenweider-OECD eutrophication study results. These results provide the technical base upon which estimates can be made of the site-specific benefits associated with controlling phosphorus inputs to a waterbody to a certain degree relative to the total nutrient load to the waterbody. Lee and Jones (1986) have found that at least a 25% reduction in the total available phosphorus load to the waterbody must occur before a discernible improvement in the planktonic algal-related water quality will occur. At this time, similar relationships have not been developed for nitrogen. However, it is likely that at least the same magnitude of control of algal available nitrogen must occur before there will be a discernible improvement in eutrophication-related water quality of a waterbody due to nitrogen input control.

Except for small urban lakes which receive their nutrients almost exclusively from urban area runoff, there will be few situations where control of nitrogen and phosphorus inputs associated with urban street and highway runoff to a waterbody will result in an improvement in eutrophication-related water quality of the waterbody. This is because HSUA stormwater runoff-associated nutrients can rarely be controlled to a sufficient degree to reduce the total nutrient load to the waterbody sufficiently to cause a discernible impact on the eutrophication-related water quality of a waterbody.

It is sometimes stated that there is need to restrict the use of fertilizers on lawns, golf courses, highway right-of-ways and other areas in order to prevent excessive fertilization downstream from the point of HSUA stormwater runoff. The development of BMPs to restrict use of these fertilizers should only be done where it has been demonstrated that the current use is, in fact, causing a significant water quality problem in the receiving waters for the HSUA stormwater runoff and where it can be shown that the projected restrictions will result in the improvement of the eutrophication-related water quality downstream of the HSUA stormwater runoff discharge.

It is concluded that it will be rare that such restrictions would be beneficial to the eutrophication-related designated beneficial uses of waterbodies receiving HSUA stormwater runoff. The areas of greatest concern will be small urban lakes that only receive nutrients from HSUA stormwater runoff. Typically, the amount of the algal-available aquatic plant nutrients derived from HSUA stormwater runoff is small compared to that derived from other sources such as rural runoff and domestic wastewater inputs.

For those few instances where aquatic plant nutrients in HSUA stormwater runoff are found to be a significant cause of eutrophication-related water quality use impairment, it would then be possible to develop site-specific BMPs to control the specific source of the available forms of the key nutrient that is contributing to the excessive fertility in the receiving waters. If this control is projected to be effective in bringing about an improvement in water quality, then such BMPs should be implemented to the maximum extent practicable.

Oxygen Demand

Frequently, HSUA stormwater runoff monitoring programs will include measurement of biochemical oxygen demand (BOD) and/or chemical oxygen demand (COD) as part of the monitoring of the runoff. While HSUA stormwater runoff can readily have measurable amounts of BOD, it is unlikely that this BOD will be of any significance in affecting the oxygen resources of the receiving waters for the runoff. As discussed above, however, the aquatic plant nutrients added to a waterbody, can be a significant source of nutrients that stimulates algal growth which, in turn, leads to oxygen depletion in a waterbody's sediments and for a stratified waterbody, its hypolimnion.

Site-specific evaluation of the oxygen resources of a waterbody should be conducted to determine if BOD associated with HSUA stormwater runoff is a significant contributor to the impairment of a waterbody's beneficial uses due to low DO. If such impacts are found, then appropriate BMPs can be developed to control the BOD input to the waterbody from HSUA stormwater sources. The approach that would be followed would focus on the specific sources of the high BOD materials in the stormwater runoff and then controlling the source of the high BOD materials.

Petroleum Hydrocarbons - Oil and Grease

This section focuses on the bulk effects of accumulated oil and grease and does not address the aquatic life toxicity of petroleum hydrocarbons present in petroleum products. Those problems are considered under aquatic life toxicity for the water column and sediments. The stormwater runoff from HSUA typically contains small amounts of petroleum hydrocarbons which can, under certain situations, cause water quality problems in receiving waters for the runoff.

In most situations, there is no need to try to treat the HSUA stormwater runoff to remove oil and grease since the small amounts of oil and grease ordinarily in this runoff do not cause significant water quality use impairments in the receiving waters. However, there are situations where petroleum hydrocarbons derived from oil and grease can be an important cause of water quality use impairments for HSUA stormwater runoff.

As part of the evaluation monitoring program, the receiving waters should be periodically visually examined to determine if there are areas where oil and grease from the HSUA stormwater runoff accumulate to a sufficient extent to be detrimental to aquatic life and other beneficial uses of the waterbody. Of particular concern would be fish spawning areas which accumulate sufficient amounts of petroleum hydrocarbons to be adverse to fish reproduction.

If the receiving waters are found to accumulate oil and grease from HSUA stormwater runoff to a sufficient extent to be adverse to the designated beneficial uses of the waterbody, then a site-specific BMP can be developed which would control the input of oil and grease to the maximum extent practicable and, if necessary, treat the runoff waters to remove the oil and grease to the extent necessary to prevent adverse impacts. Before expensive treatment is undertaken, however, attempts should be made to control the petroleum hydrocarbon contribution to the HSUA runoff based on source control activities. The most likely source of oil and grease in runoff is near the toll plazas. The runoff waters from these areas will be treated for oil and grease removal.

Aquatic Life Carcinogens

Aquatic life in some areas, especially associated with petroleum hydrocarbon refining and industrial processes that introduce large amounts of PAHs into a waterbody, has been found to have tumors, lesions and other illnesses associated with the chemicals that are carcinogens. While this is apparently not a problem associated with HSUA stormwater runoff, it would be important to examine some of the aquatic organisms in an area receiving such runoff to determine if they have tumors, liver or other organ lesions, abnormal organs, etc. that could be attributable to the runoff. If problems of this type are found that are tied to HSUA stormwater runoff, then site-specific BMPs can be developed to control at the source and, if necessary, treat the stormwater runoff to control the problem. This treatment would likely involve removal of petroleum hydrocarbons beyond that currently planned for the toll plaza area runoff. It is important to emphasize, however, that it is not anticipated that such treatment would be needed.

Sanitary Quality

HSUA stormwater runoff typically contains elevated concentrations of fecal coliforms and other organisms that are indicators of waterborne enteric pathogens. The sanitary quality (contact recreation - swimming, wading and shellfish harvesting) of the receiving water for HSUA stormwater runoff can be adversely impacted by fecal coliforms (total coliforms for shellfish). The development of BMPs for HSUA stormwater runoff to address the control of enteric pathogenic organism indicators such as fecal coliforms should be based on finding excessive concentrations of these organisms in receiving waters for the runoff that impair the use of these waters.

Excessive concentrations are usually manifested in beach or swimming area closures and/or restrictions on shellfish harvesting. If such closures and/or restrictions of use are present in receiving waters for HSUA stormwater runoff, it is necessary to determine whether the runoff is, in fact, a significant contributor to the frequency of closure - restrictions. If this situation is found, then it will be important to determine whether there are connections between the sanitary sewerage system and the stormwater sewerage system which allow domestic wastewaters to enter the stormwater system during runoff periods.

Lee and Jones (1991c) have reported on the results of a study conducted in Lubbock, Texas where an evaluation was made on the impact of urban stormwater runoff-derived fecal coliforms and streptococci on recreational water quality in the Yellowhouse Canyon Lakes. These lakes are a chain of small lakes in a city park that receive appreciable stormwater runoff from the urban area. It was found that immediately after a stormwater runoff event, the sanitary quality of these lakes decreased to the point where they were considered unsafe for contact recreation, such as swimming. However, within a week to two weeks after the runoff event, the water in the lakes again met sanitary quality standards for contact recreation. During this period there was sufficient removal of the fecal indicator organisms through die-off and sedimentation to reduce their numbers below the fecal coliform standards.

Often today there is an attempt to distinguish between fecal indicator organisms derived from humans vs. animals through determination of fecal coliform - fecal strep ratios in swimming area closure situations. If these ratios indicate that the fecal indicator organisms are derived from animal rather than human sources, then it is generally determined that there is less need for the closure of the contact recreation area. However, justification for this approach is highly questionable based on the fact that *Cryptosporidium* is derived, at least in part, from cattle and possibly other animals. This organism is becoming recognized as an important cause of enteric disease associated with domestic water supplies and contact recreation (Lee and Jones-Lee, 1993c, 1994f, 1995h). This is the organism that was responsible for causing approximately 400,000 people in Milwaukee, Wisconsin to become ill and about 100 people to die in a water supply waterborne epidemic in the spring of 1993. The source of this organism was believed to be from cattle where stormwater runoff waters containing cattle feces entered the Milwaukee raw water supply.

An area that is receiving increasing attention as a potential source of enteric pathogenic organisms is the use of reclaimed wastewaters for irrigation of ornamental shrubbery and other areas such as highway right-of-way shrubbery. As discussed by Lee and Jones-Lee (1995h), some regulatory agencies such as the California Department of Health Services (CA DHS) allows the irrigation of ornamental shrubbery and golf courses with reclaimed domestic wastewaters that have not been adequately disinfected to control enteric viruses and cyst-forming protozoans such as *Cryptosporidium*. Disinfecting a domestic wastewater to just meet fecal coliform standards does not provide adequate disinfection to necessarily kill all the pathogenic enteric viruses and protozoan cysts. The use of partially treated reclaimed wastewaters to irrigate shrubbery along highways, in parks, golf courses, etc. could lead to potential water quality problems associated with HSUA stormwater runoff.

The BMP for such problems would involve more appropriate disinfection of the reclaimed wastewaters before reuse. Lee and Jones-Lee (1995i) have recently provided guidance on the water quality monitoring program that should be conducted to determine whether reclaimed domestic wastewaters represent important sources of fecal organisms that would represent a significant threat to the sanitary quality of a waterbody. They recommend that in addition to monitoring for fecal coliforms, the monitoring program should include measurement of enteroviruses and cyst forming protozoans such as *Cryptosporidium* and *Giardia*.

If it becomes necessary to disinfect HSUA stormwater runoff in order to prevent this runoff from causing impaired water quality in the receiving waters for it, it will be important to remove the residual disinfectant, such as chlorine, to be sure that it is not adverse to aquatic life in the receiving waters.

Groundwater Recharge

In many areas, HSUA stormwater runoff recharges groundwater basins. The chemical constituents and pathogenic organisms in the runoff can potentially be a threat to groundwater quality. While in most instances the constituents in HSUA stormwater runoff will not significantly alter the potential for the receiving waters to impair the uses of groundwater, there may be unusual situations where groundwater quality could be impaired by constituents in HSUA stormwater runoff. Typically, the additional loads of constituents in runoff water are such that they do not significantly change the concentrations of constituents of concern for groundwater quality through the recharged waters. Further, many of the constituents with elevated concentrations in HSUA stormwater runoff are in particulate forms which are removed from the recharge waters as the receiving waters plus the runoff waters percolate into the aquifer system.

Some of the dissolved constituents in highway runoff will be sorbed into the vadose zone (unsaturated) and saturated zone of the aquifer and thereby not cause groundwater quality - use impairment. The aquifer mobile fraction of the chemical constituents in the runoff waters such as nitrate, chloride, sodium, etc. are normally present in HSUA stormwater runoff waters at concentrations that do not represent threats to groundwater quality. An exception to this situation is detention - infiltration basins where the constituents in the HSUA stormwater runoff are not diluted in the receiving waters for the runoff. Under these conditions, it is possible to build up sufficient concentrations of some chemical constituents in the recharge waters to be a threat to groundwater quality.

At a location where HSUA stormwater runoff is recharged directly or is a significant component of receiving waters that recharge an aquifer, such as in areas where infiltration of stormwater is used for stormwater runoff management, a site-specific evaluation should be made to determine whether the recharge waters are adversely impacting the quality of the waters in the aquifer. Typically, this is best done by sampling the groundwaters immediately under the recharge areas and down groundwater gradient of the recharge point. If excessive concentrations of chemical constituents are found in the groundwaters that can be attributed to recharge, then evaluations should be made as to whether these constituents are derived to a significant extent from HSUA stormwater runoff.

A special area of concern with respect to groundwater pollution by stormwater runoff is the potential for accidental spills of chemicals to cause pollution of aquifer systems. It is important, as part of developing an accidental spill contingency plan, to be able to contain the spill as much as possible in areas in which there is low permeability aquifer materials or paved surfaces as a barrier between the spilled chemicals and the water table. Further, in the event of a spill, those responsible for managing HSUA stormwater runoff should be prepared to be able to quickly begin remediation of the contaminated parts of the aquifer to prevent the spread of the spilled chemicals through the unsaturated - vadose zone and into the water table.

Domestic Water Supply Water Quality

Since chemical constituents and pathogenic organisms in HSUA stormwater runoff are threats to domestic water supply raw water quality, it will be important to evaluate whether stormwater runoff from these areas is significantly adverse to a water utility's use of a waterbody as a raw water supply. For most water quality parameters, the evaluation monitoring approach discussed herein which focuses on defining real water quality problems of significance to aquatic life and recreational uses of waters will, in general, detect significant water quality problems for domestic water supplies. There are, however, some exceptions to this situation.

There are certain chemical constituents and pathogenic organisms in waters which are of concern because of their impact on raw water supply water quality. Examples would be low molecular weight organics which are potential carcinogens which do not bioaccumulate in fish tissue to a sufficient extent to cause health hazards for human consumption or consumption by higher trophic level organisms. Chemicals of this type are the VOC's (low molecular weight chlorinated solvents and volatile organics such as benzene).

A chemical that could become extremely important in affecting domestic water supplies but not other beneficial uses of waterbodies is arsenic. Dependent on the concentration that the US EPA selects as the new Maximum Contaminant Level (MCL) for arsenic as part of its current review process, arsenic could become one of the most important parameters influencing raw water quality. It is of concern because of its potential to cause cancer and other diseases in people. Some stormwater runoff studies have shown arsenic from urban areas to be at concentrations above some of the US EPA's proposed MCL's. In time, considerable attention will be given to specific sources of arsenic which cause a waterbody to have concentrations of arsenic that require treatment for use of the water for domestic water supply purposes. When this occurs, the sources of arsenic in HSUA runoff will need to be determined to ascertain if the elevated concentrations of arsenic in the runoff can be controlled at the source.

Another group of chemicals of potential concern are the trihalomethane precursors (dissolved organic carbon - DOC) that are derived from the decay of terrestrial and some forms of aquatic vegetation. Eventually, the US EPA and state regulatory agencies will be attempting to control sources of DOC for waterbodies in an effort to reduce the DOC content of the raw water. While various types of land use have differing DOC export coefficients (g of DOC/m^2/yr), insufficient information is available at this time to indicate that stormwater runoff from highways and urban areas is a particularly significant source of DOC. This is an area that needs attention in any evaluation monitoring program. Further information on evaluation and management of domestic water supply raw water quality is found in the review by Lee and Jones (1991d).

The impact of HSUA stormwater runoff on domestic water supply water quality needs to be considered from two perspectives: surface or groundwater-based water supplies. The basic issue is whether HSUA stormwater runoff introduces new constituents in sufficient amounts to be a significant threat to domestic and other water supply water quality. Both human health (hazardous chemicals and pathogenic organisms) and aesthetic quality should be considered, including taste and odor producing compounds, hardness, total dissolved solids (TDS) and other constituents that can impact domestic water supply water quality. In situations where there is already appreciable HSUA stormwater runoff contributed to a domestic water supply, the issue then becomes one of whether the additional load of HSUA stormwater runoff-derived constituents represents a significant additional load that either causes the water utility to start to have to treat to remove the constituents or to have to increase treatment costs to remove the additional load of constituents.

For domestic water supplies that are based on groundwater sources, the issue becomes one of assessing the potential for HSUA stormwater runoff-derived constituents to adversely impact the groundwater that is recovered from the area where HSUA stormwater runoff-derived constituents are recharged into the aquifer system. While many aquifers have an appreciable ability to remove - "treat" chemical constituents in recharged waters through soil aquifer treatment, there is a potential for build-up of persistent chemicals and/or transformation products of treated chemicals within the aquifer system. As discussed by Lee and Jones-Lee (1993d, 1994g,h) concern must also be given to whether constituents in recharged waters could cause the aquifer to become contaminated to a sufficient degree to lead to the need for aquifer remediation in a Superfund-like program.

All groundwater-based water utilities should be monitoring the characteristics of the recharged waters near the point of recharge to detect incipient water quality problems. HSUA stormwater runoff-derived constituents of potential concern should be added to the list of aquifer-based monitored parameters. Similarly, surface-based water supply systems should be conducting a detailed monitoring program of the raw water quality. If any of the HSUA stormwater runoff-derived constituents represent a threat to the surface water quality, groundwater or aquifer quality, then site-specific BMPs should be developed to control the constituents at the source or to treat the HSUA stormwater runoff to protect the water supply water quality.

Litter and Debris

HSUA stormwater runoff can carry appreciable quantities of litter and debris which can impair the use of areas receiving the runoff. A key part of evaluation monitoring is determination of whether litter and debris typically associated with HSUA stormwater runoff is present in the receiving waters to a sufficient extent to impair the uses of the waterbodies and their nearshore associated areas. If visual inspection of the receiving waters shows that areas of this type occur, then improved litter and debris control can be implemented to eliminate the use impairment that is occurring associated with the materials carried in the runoff.

Evaluation of the Impacts of Specific Chemical Constituents in Stormwater Runoff

The end-of-the-pipe stormwater discharge monitoring that has been done has shown that HSUA stormwater runoff in many parts of the US contains elevated concentrations of a variety of chemical constituents and waterborne pathogenic indicator organisms that represent potential threats that could impair uses of receiving waters for the runoff. As is well-known today, however, the characteristics of these constituents and stormwater runoff events greatly diminishes, and for some constituents eliminates any use impairment in the receiving waters associated with the elevated concentrations of the constituents in the runoff waters within a short distance in the receiving waters for the stormwater runoff discharge. The evaluation monitoring program is designed to screen the receiving waters from real use impairments due to the exceedances of water quality standards in the runoff waters by screening for significant persistent toxicity in the receiving waters associated with runoff events. If no toxicity is found in the receiving waters for the stormwater runoff associated with a runoff event, then there is no need to make measurements of specific chemicals that are of concern because of their potential toxicity. Similarly, by screening the edible aquatic organism tissue in the receiving water for excessive bioaccumulation, it is possible to rule out those regulated chemicals that represent threats of bioaccumulation.

If, however, significant toxicity or excessive bioaccumulation is found in the receiving waters that can be associated with stormwater runoff from HSUA, then site-specific studies can be conducted to determine the specific cause and source of the water quality problem. These, in turn, would lead to the development of BMPs that would specifically address the control of real water quality problems that are found. Lee and Jones-Lee (1996b) have recently presented a discussion on the need to use evaluation monitoring in the development of technically valid, cost-effective BMPs for HSUA stormwater runoff.

Since it will be difficult to break the habit of focusing monitoring programs on specific chemical constituents where the results are mechanically compared to water quality standards, irrespective of duration of exposure and available form considerations, it is important, that to the extent that specific chemical constituents are monitored in the receiving waters, that this monitoring determine whether there is a potentially significant increase in the receiving waters of potentially hazardous forms of the constituent which could be detrimental to receiving water quality. The receiving water monitoring program should specifically address whether the stormwater runoff causes a measurable increase in regulated chemicals. These measurements should be made close to the point of entry of the stormwater runoff into the receiving waters but outside of the physical mixing zone for the stormwater runoff and the receiving waters.

The physical mixing zone is not necessarily the same as the regulatory mixing zone that is often arbitrarily established associated with NPDES point source discharges. Typically for such discharges, current regulatory approaches prohibit exceedance of water quality standards outside the regulatory defined mixing zone. This approach leads to over-regulation of chemical constituents in point source discharges since the size of the mixing zone is less than that which could be allowed to protect the designated beneficial uses of the receiving waters without significant, unnecessary expenditures for chemical constituent control.

The physical mixing zone associated with stormwater discharge is the area of the waterbody receiving the discharge where mixing occurs within a short time after discharge. For streams and rivers, it is typically defined as the reach of the river where the concentrations of constituents in the receiving waters and the runoff are mixed to greater than 90%, i.e. the concentrations across the river that result from the discharge should not vary more than about 10%. For lakes, large rivers, estuaries and the ocean, the mixing zone can be defined in terms of the region of the receiving waters in which the time concentration profile for the discharge water plume is such that no adverse impacts on receiving water water quality would be expected because the planktonic aquatic organisms in the plume do not receive an excessive concentration - duration of exposure relationship for the potentially toxic constituents in the discharge. The focus in the evaluation is on short-term, acute effects within this mixing zone. The evaluation monitoring then considers whether longer-term, chronic effects arise from the specific chemical constituents of concern outside of this mixing zone.

If chemical measurements are to be used for specific constituents, then total recoverable and dissolved fractions should be measured, recognizing that the dissolved fraction of metals, organics, nutrients, etc., is the fraction that best estimates potential adverse impacts. While at this time the US EPA has only indicated that it will allow the dissolved fraction of certain metals in ambient waters to be used in regulatory programs, in time, the Agency will likely adopt similar approaches for other constituents which are potentially toxic to aquatic life in the receiving waters, such as organics. It is well known through work on sediment criteria development that the particulate fraction of organics, like the particulate fraction of metals, is not available and is non-toxic.

If measurement of the dissolved fraction of a regulated chemical which is of concern because of its potential to cause toxicity to aquatic life or to lead to excessive bioaccumulation within aquatic organism tissue shows potential water quality problems, then follow-up studies should be conducted to evaluate whether the apparent excessive concentrations represent potentially significant use impairments in the receiving waters for the runoff. This can best be done by conducting toxicity tests and/or determining whether excessive bioaccumulation is occurring in aquatic organism tissue for receiving water organisms. If no toxicity is found in the receiving water in properly conducted tests that reflect the concentration - duration of exposure relationships that occur in the receiving waters for this stormwater discharge, then it is possible to rule out the exceedance of the water quality standard/objective as representing a real water quality use impairment for potentially toxic chemicals.

If, however, significant toxicity is found in the receiving waters, then site-specific studies need to be conducted to determine the cause of the toxicity and whether it is due to constituents associated with stormwater runoff. Normally this can be ascertained based on measurements of toxicity within and outside of the runoff plume. Lee and Jones (1991a) have discussed approaches that can be used for following the runoff plume in the receiving waters where measurements are made within the plume and outside of the plume along a drogue path.

Any sampling that is done for specific chemical constituents should be done with "clean techniques" such as those described by the US EPA (1993d). It is now known that most of the heavy metal and some other chemical constituent data that have been collected on runoff waters and receiving waters over the last 15 years are unreliable due to the failure of those conducting the studies to properly sample and to protect the collected samples from contamination during sampling and sample handling. Clean techniques are necessary to avoid contaminating the samples and yielding artificially high values for chemical constituents of concern.

Aquatic Organism Assemblages

The evaluation monitoring program discussed herein focuses on utilizing biological effects-based test responses, such as toxicity tests, that can give an indication of a water quality use impairment that is occurring in the receiving waters for the HSUA stormwater runoff. The bottom line issue with respect to the development of BMPs to control aquatic life resource impairment is whether the numbers, types and characteristics of the aquatic organisms in the receiving waters for the HSUA stormwater runoff are sufficiently adversely impacted so that the public, who must fund remediation - control programs, finds that control of the constituents responsible for the use impairment through the implementation of BMPs to the maximum extent practicable should be implemented. In those situations where the testing procedures, such as ambient water toxicity tests, predict significant impairment as a result of finding widespread prolonged toxicity associated with a runoff event, the evaluation monitoring program should include examination of the numbers, types and characteristics of the biological organisms within the receiving waters to be certain that the toxicity tests have reliably predicted the adverse impacts.

The US EPA is developing biological criteria which are specifically designed to evaluate whether the numbers, types and characteristics of the organisms in a waterbody have been adversely impacted by input of chemical constituents. The agency has developed a biological criteria guidance manual that provides guidance in making this type of evaluation (US EPA, 1990b). Further, the Agency has recently revised its Water Quality Criteria Handbook which should be consulted for further information (US EPA, 1994d). It is important, however, in making an evaluation of this type, to clearly distinguish between the impact of habitat characteristics and physical factors, such as climate, flows, storms, etc., that may influence aquatic organism assemblages and those that are due to chemical constituents derived from HSUA stormwater runoff. Lee and Jones (1982) have provided guidance on how to utilize aquatic habitat information in determining whether chemical constituent input to a waterbody (streams and rivers) is adversely impacting the number, types and characteristics of organisms that could be present in the waterbody based on the waterbody's habitat characteristics.

Evaluation Monitoring Beyond Initial Evaluation

The initial screening evaluation monitoring discussed herein will detect significant water quality use impairments in the receiving waters for the stormwater runoff. After completion of the initial screening, there would be need to continue the evaluation monitoring program where ongoing studies would be conducted that are designed to try to detect subtle impacts of runoff-associated constituents on the beneficial uses of the receiving waters that are not detected in the initial screening. As real water quality use impairments are controlled and as additional information is gathered on the receiving waters, less obvious use impairments may become evident. Further, through the development of new chemicals and changes in the use of existing chemicals, it is possible that new water quality problems will develop in the future that do not exist now or are not recognized now. As more is learned about the impacts of chemicals on aquatic organisms, new adverse impacts are being found that need to be considered in any water quality evaluation. The traditional, end-of-the-pipe constituent monitoring will not reliably detect new water quality problems; however, the evaluation monitoring program which focuses on detecting receiving water impacts can detect the new problems and provide a technical base for their control.

It is envisioned that the evaluation monitoring program would be an ongoing program where all use impairments would not be addressed at one time. Instead, the expected use impairments of a waterbody would be prioritized in terms of importance to the public, and over a five year permit period, each of the potentially significant water quality use impairments would be addressed. This same type of use impairment would then be examined again at approximately five year intervals.

Evaluation Monitoring as Part of Watershed Water Quality Management

The State Water Resources Control Board and the Santa Ana Regional Water Quality Control Board as well as Orange County Environmental Management Agency are in the process of adopting a watershed-based water quality management approach for the various major waterbodies in the state and Orange County. Both the Santa Ana River system and Upper Newport Bay watersheds are part of a watershed water quality management programs. The evaluation monitoring program for the highway will provide support for the implementation of the watershed management programs. By determining the real water quality - use impairment for each of the waterbodies receiving the highway runoff and by identifying the cause and the source of the constituents causing the water quality impairment, it will be possible to help implement a technically valid watershed-wide management program. Those responsible for managing water quality for constituents derived from other parts of the watershed will ultimately become involved in similar kinds of water quality use impairment evaluation and management programs as those being developed for the highway.

Accidental Spill Containment

One of the areas of particular concern in developing BMPs for highway runoff is the containment of accidental spills of chemicals and fuel that occur on the highway or its shoulder. In developing BMPs for a highway, it is important to incorporate into the stormwater runoff management program approaches that can be readily used to contain accidental spills of chemicals that can occur in areas where the spill could rapidly enter a sensitive waterbody. Efforts should be made to assist the local transportation agency/stormwater management agency in implementing accidental spill containment contingencies through the design of emergency runoff control structures, such as easily implemented check-dams, stormwater outlet flow control devices, etc., to the maximum extent possible to prevent spilled chemicals and fuel from entering the waterbodies.

BMPs and Hazardous Wastes

Some of the structural BMPs that are being developed today for HSUA stormwater runoff, such as detention basins and filters, are accumulating sufficient concentrations of chemical constituents originally present in the runoff to cause the sediments that collect within the structures to be classified as a hazardous waste. It is important in designing and operating structural BMPs for HSUA stormwater runoff to consider whether the materials that accumulate within them are classified as hazardous wastes since such a classification greatly changes the cost of residue management. It is also important to design stormwater runoff conveyance structures, drop inlets, etc. so that they do not accumulate particulates in HSUA stormwater runoff that could be classified as a hazardous waste. While such classification is based on inappropriate, arbitrarily developed definitions evolving out of the federal and state regulatory agencies' approaches for managing hazardous wastes, this classification is costing some stormwater management entities large amounts of money, in managing as hazardous waste, the residues that accumulate within the stormwater management conveyance systems. It is important to note, that with few exceptions, these materials are not particularly hazardous to workers who may come into contact with them or to the environment. They are, however, hazardous wastes based on the arbitrary approaches that have been used to define hazardous wastes which consider how the materials would behave in a sanitary landfill, and therefore, must be managed as such unless a variance is issued exempting this type of management.

The Realities of Pollution Prevention

The notion which is sometimes advocated in water pollution control programs that every little bit of "pollution control" helps is not technically valid and can be detrimental to developing meaningful water quality management programs for a region. For every water quality pollution control program there should be developed, as part of its implementation, a clear, well-defined assessment of the receiving water designated beneficial use benefits that will accrue as a result of implementation of the pollution control program. Considering current fiscal limitations within the public sector, capital and maintenance expenditures must be focused on the most acute water quality problems rather than implementing sweeping but less intensive programs that are only partially effective or are non-effective.

An example of this type of situation occurs in HSUA stormwater runoff where detention basins have been adopted as a water quality BMP in which property developers, private, state and federal highway agencies and municipalities acquire lands and provide the maintenance for the development and operations of a detention basin that removes particulate forms of constituents in HSUA stormwater runoff. While detention basins can be justified if there is a significant erosion problem that needs to be controlled and cannot be controlled at the source where erosion is occurring, there is no valid justification for using detention basins to control particulate forms of constituents in HSUA stormwater runoff as a result of the US EPA's May 1995 adopted approach of focusing control programs on ambient water soluble forms of heavy metals. Detention basins and other structural BMPs, such as grassy swales, vegetative areas, etc., should only be constructed where there is a technically valid, well-founded, expected significant improvement in the designated beneficial uses of the waterbody for the HSUA stormwater runoff.

Frequently, today the advocates of pollution prevention programs focus their efforts on the control of chemical constituents such as heavy metals in storm water runoff without regard to whether the heavy metals in such runoff are in toxic-available forms. An example of this type of situation occurs in San Francisco Bay, where it is advocated that there is need to force the automobile brake pad manufactures to remove copper from the brake pads since the wear of the brake pads results in elevated concentrations of copper in highway and street runoff. However, it has been found that the copper in San Francisco Bay from all sources, including highway runoff, is not adverse to the beneficial uses of the bay waters. Therefore, the control of copper in automobile brake pads does not represent a control of a pollutant, i.e., a constituent that impairs use, but represents control of a chemical constituent that will have no impact on the beneficial uses of San Francisco Bay.

A similar situation exists today with respect to the Santa Monica Bay restoration program, where this program is directed toward the control of chemical constituents in urban stormwater runoff independent of whether these constituents have any impact on Santa Monica Bay water quality - beneficial uses. Such approaches can be wasteful of public and private funds and result in misdirecting pollution prevention programs to unimportant areas. It is important, therefore, in developing technically valid <u>pollution</u> prevention programs, to focus these programs on those constituents, i.e., specific forms of chemicals, which are, in fact, pollutants. This will require the use of an evaluation monitoring program of the type described herein in formulating and implementing the pollution prevention program.

Ecologically sensitive - important, currently un-impacted areas should receive particular attention in developing BMPs for HSUA stormwater runoff. Important fish and shellfish spawning areas that are not now receiving substantial amounts of HSUA stormwater runoff should receive special attention. For example, the oil and grease and other petroleum hydrocarbons from a new major highway that enters a pristine area stream that is used for salmonid reproduction where the hydraulic characteristics of the water would promote the accumulation of oil and grease in the spawning bed area, should be prime targets for BMP development to control oil and grease runoff from the highway.

Summary of Evaluation Monitoring Approach

Presented below is a summary of the key components of the evaluation monitoring approach to determine whether runoff-derived constituents from highway, street and urban areas are causing a significant adverse impact on the designated beneficial uses of the waterbodies receiving the runoff.

Toxicity Measure the aquatic life toxicity using larval fish, shellfish and zooplankton in the receiving waters for the runoff associated with runoff events to determine if regulated, as well as unregulated, constituents in the runoff are causing sufficient aquatic life toxicity to be potentially adverse to the designated beneficial uses of the waterbody receiving the runoff.

Bioaccumulation Measure edible tissue residues of non-migratory - resident fish and shellfish populations in the area of the runoff to determine if excessive concentrations of runoff-derived constituents are occurring in edible organisms that cause the organisms' tissue to receive a consumption health advisory. Also, consider the concentrations of chemical constituents in the whole organism that represent potential problems for wildlife that use the organism as food based on the US EPA's Great Lakes Initiative wildlife-based criteria. The focus should be on actual tissue residues in fish that are used as wildlife food and not on chemical concentrations in the water that, under certain conditions, can lead to excessive concentrations of the chemical constituent in fish or other aquatic life that, in turn, represent hazards to wildlife through the consumption of the aquatic life.

Sanitary Quality In order to assess whether the sanitary quality of the receiving waters associated with stormwater runoff from a particular area is significantly adversely affecting contact recreation or shellfish harvesting, it is necessary to determine the relative contributions of waterborne pathogenic indicator organisms, such as fecal coliforms, from the runoff compared to other sources. Such information can then be used to assess whether it may be appropriate to consider disinfecting the stormwater runoff to improve the sanitary quality of the receiving waters for the runoff.

Eutrophication To evaluate whether the aquatic plant nutrients, nitrogen and phosphorus compounds in stormwater runoff are contributing to excessive fertilization of the receiving waters for the runoff, it is necessary to estimate the relative significance of runoff-derived available forms of nutrients that control aquatic plant growth in the receiving waters vs. these same forms of nutrients derived from other sources.

Contaminated Sediments In order to evaluate whether stormwater runoff-associated particulate contaminants are causing significant water quality - use impairments in receiving water due to the runoff-derived contaminants' accumulation in receiving water sediments, it is necessary to first determine whether the receiving water sediments are the cause of a significant use impairment of the waterbody in which they are located. If such a use impairment is found, then an evaluation should be conducted of the specific chemical constituent and its form that causes this use impairment and the sources of this chemical constituent. If stormwater runoff is found to be a significant source of the chemical constituent of concern, then the sources of that constituent (specific chemical form) responsible for the use impairment should be determined.

Petroleum Hydrocarbons The potential impact of petroleum hydrocarbons (oil and grease) on receiving water quality should be evaluated on a site-specific basis focusing on determining whether those conditions for petroleum hydrocarbon accumulation are occurring in the receiving waters for the runoff. If accumulation does occur, then the significance of this accumulation needs to be assessed with particular reference to situations in which the accumulation occurs in ecologically sensitive areas that could be significantly detrimental to aquatic life populations, such as through adversely impacting fish spawning or shellfish.

Litter Visual reconnaissance of the receiving waters for the runoff should be conducted to determine if litter is being derived from this runoff which impairs the uses of the receiving waters.

Domestic Water Supply The significance of HSUA runoff as a source of the constituents that cause domestic water supply utility problems in treatment and/or increased costs should be ascertained.

Development of BMPs In developing BMPs to control to the maximum extent practicable the real water quality - use impairment (pollution) of the receiving waters for the stormwater runoff, it is necessary to first find significant pollution of the receiving waters for this runoff. Once this use impairment - pollution has been identified, then site-specific studies need to be conducted to determine the specific sources of the constituents that are present in HSUA runoff that cause the receiving water use impairment. Once these sources have been identified and quantified, then BMPs can be developed to control the constituents of concern at the source to the maximum extent practicable. If source control does not eliminate the significant adverse impact of the constituents in the runoff, then treatment of the runoff with site-specifically developed BMPs should be implemented. This implementation program should be part of an area-wide, watershed based implementation program to control similar types of HSUA runoff.

Ongoing Evaluation Monitoring In order to detect subtle water quality impacts from current stormwater discharges that were not found in the evaluation monitoring initial screening, as well as new water quality problems arising from the introduction of new chemicals or new forms of chemicals into HSUA stormwater runoff, an ongoing evaluation monitoring program should be conducted. Periodically, such as once in every five year NPDES permit period, each of the components of the evaluation monitoring program should be initiated again.

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List of Acronyms

BMP - Best Management Practices

BOD - Biochemical Oxygen Demand

CA DHS - California Department of Health Services

COD - Chemical Oxygen Demand

COE - Corps of Engineers

DO - Dissolved Oxygen

DOC - Dissolved Organic Carbon

HSUA- Highway, Streets and Urban Area

MCL - Maximum Contaminant Level

TDS - Total Dissolved Solids

TIE - Toxicity Investigation Evaluation

TOC - Total Organic Carbon

US ACOE - US Army Corps of Engineers

US EPA - US Environmental Protection Agency

VOC - Volatile Organic Chemicals

Application of Evaluation Monitoring to BMP Refinement for a Highway Stormwater Runoff Water Quality Management

The Highway (HGW) is a new 26 mile highway that is being constructed in Sothern California . Construction on the HGW began in the summer of 1995 and is expected to be completed in 2,000. The HGW consists of Two major legs.

the North leg that drains into the SA River and the South Leg that drains into a SD creek that enters a estuarine Bay. Presented below is a discussion of the application of evaluation monitoring to the refinement of BMPs to control the water quality impacts associated with chemical constitutents and pathogenic organisms in HGW stormwater runoff.

The application of the evaluation monitoring program presented below specifically considers the impacts of HGW stormwater runoff on each of these waterbodies.

The evaluation monitoring program is a primary element in the formulation of an effective post-construction HGW stormwater runoff water quality management program. Protection of the designated beneficial uses of the receiving waters for HGW stormwater runoff is the primary objective of this program. Validation and verification of the selected BMPs also will be accomplished with the implementation of the evaluation monitoring program.

Basically the evaluation monitoring program for HGW recognizes the current lack of information relative to the water quality significance of chemical constituents and potential pathogenic organisms in HGW runoff as they may impact the designated beneficial uses of the receiving waters for this runoff. This program also recognizes that many traditional stormwater runoff BMPs, such as detention basins, have limited effectiveness in controlling water pollution - use impairment associated with the chemical constituents in runoff.

Rather than following a traditional effluent limitations approach of highway runoff BMP development which assumes that all exceedances of water quality standards caused by chemical constituents and pathogenic organism indicators in the runoff waters result in a significant impairment of the beneficial uses of the receiving waters for the runoff, the evaluation monitoring program focuses on finding actual water quality problems in the receiving waters that are caused by the runoff. By determining what real, significant water quality use impairments occur in the runoff receiving waters that are attributable to HGW runoff-derived constituents, it will be possible to develop technically valid, cost-effective source control programs that, in accord with current federal and state regulatory requirements, can be implemented to control pollution to the maximum extent practicable (MEP). The focus of post-construction BMP development is on source control in a coordinated effort with the regulatory agencies to address the control of water pollution by HGW and other highway and street stormwater runoff in the region.

Objectives of Program

The objective of the evaluation monitoring program is to develop an approach for BMP development that can be readily implemented when the HGW becomes operational in 2000. Where real water quality problems are found in the receiving waters that are due to HGW-derived constituents, then a cooperative effort with the regulatory agencies would develop appropriate BMPs that would control the water quality use impairments to the maximum extent practicable. The focus of these programs would be on source control. Structural BMPs may be employed where such an approach is appropriate in removing the chemical constituent of concern and where source control is not practical. Structural controls that have not been implemented as a part of the current program will rely on the implementation of new technology and will be a result of the evolution of standards for stormwater quality control programs for public infrastructure.

At this time, the various entities responsible for stormwater runoff water quality evaluation and management in Orange County each have their own water quality monitoring programs. These entities are generating considerable amounts of data which show that there are concentrations of various constituents in highway and street runoff that exceed water quality objectives in the runoff waters. However, thus far, these exceedances have not been tied to any water quality use impairments in the receiving waters. The evaluation monitoring program will enable the various entities to work together to define and manage stormwater runoff water quality problems through the use of the program findings within their specific areas of responsibility.

Any chemical constituent or pathogenic organism indicator found in HGW runoff to be causing water quality use impairments in the receiving waters for this runoff would also be derived from other highways and urban streets in the region. Adoption of this approach should lead to a highly coordinated, effective program for using the resources available to control real water pollution to the maximum extent practicable using technically valid, cost-effective BMPs.

Determining the Characteristics of Receiving Waters

The first step in establishing BMPs for the stormwater runoff water quality management program for a section of the HGW is to examine the characteristics of the receiving waters for the runoff. Of particular concern are the designated beneficial uses of these waters and an assessment of any existing impairment of these uses. In addition to considering the waterbodies that receive the stormwater runoff from the area of concern, consideration must also be given to the designated beneficial uses of "downstream" waterbodies into which the receiving waters for the stormwater runoff ultimately enter.

Informal discussions were held with water quality regulatory agency staff at the regional and local levels who are responsible for the evaluation and management of water quality for the waterbodies receiving the stormwater runoff to ascertain whether there are any particular concerns held by these staff on the potential impacts of the stormwater runoff from ETC on the receiving waters' water quality. These issues were also discussed with the agencies responsible for management of the waterbody and/or who utilize the waterbody's resources. The purpose~~s~~ of these discussions were background information fact-finding and an assessment of regulatory agency approaches toward regulating chemical constituents in ETC stormwater runoff.

Information has been collected on the current stormwater runoff and receiving water quality monitoring programs for the waterbodies that would receive the ETC stormwater runoff of concern. At the time of implementation of the evaluation monitoring program, the additional data that has been collected between now and then will be critically examined for data reliability and any inference they may provide on actual water quality use impairments that are occurring in the receiving waters for ETC runoff. Any exceedances of water quality standards that may be occurring near the point of discharge where the stormwater runoff enters the waterbody as well as throughout the waterbody, or a significant part thereof, will be determined relative to the stormwater runoff inputs.

Of particular concern is the assessment of any real use impairments of the waterbodies receiving the ETC stormwater runoff that are of concern to the public who may use these waters for various purposes, such as domestic, industrial or agricultural water supply, fish and aquatic life, recreation, aesthetic enjoyment, etc.

To the extent possible, previous reports on the water quality issues associated with the receiving water for ETC stormwater runoff have been obtained and critically reviewed. Further, at the time of implementation of the evaluation monitoring program, any new data and reports on stormwater runoff receiving water characteristics will be reviewed following the approaches discussed by Lee and Jones-Lee (1992) and include detailed review of the reliability of the sample collection, handling and analytical procedures used. Also, an in-depth review of the technical validity of the analytical methods used would be conducted in accord with the procedures discussed by Lee and Jones-Lee (1992). As they indicate, it should not be assumed that because standard analytical procedures were used, such as the APHA *et al.* (1995) "Standard Methods" and/or US EPA (1983) methods, and that because generally accepted QA/QC methods are followed, the data obtained in a water quality investigation are necessarily reliable.

It is important in reviewing existing waterbody water quality information to ascertain how well water quality use impairments have, in fact, been assessed. It is important not to assume that an exceedance of a water quality standard in the receiving water necessarily means that this represents a real use impairment of concern to the public. As discussed by Lee and Jones-Lee (1995f) and herein, concentrations of various constituents present in HSUA stormwater runoff can greatly exceed water quality objectives without adverse impacts on the beneficial uses of the receiving waters. It is often found especially associated with HSUA stormwater runoff that the so-called "water quality use impairment" represents an administrative exceedance of an overly-protective water quality standard that has been adopted by the state and/or federal regulatory agencies. In order for there to be a real water quality use impairment for aquatic life-related designated beneficial uses of waterbodies, the numbers, types and characteristics of desirable aquatic organisms must be significantly adversely impacted in the waterbody receiving the HSUA stormwater runoff.

Preliminary Evaluation of HSUA Existing Constituent Loads to Receiving Waters

One of the first steps in developing an evaluation monitoring program is to estimate the total amount of HSUA stormwater runoff input of chemical constituents and enteric pathogenic organism indicators to the waterbody of concern. This can normally be done for HSUA stormwater runoff through highway and urban runoff chemical constituent export coefficients and/or average concentrations in HSUA stormwater runoff and the total estimated water runoff from the watershed of concern. The purpose of making this estimate is to determine whether the HSUA stormwater runoff would likely be a new, unique source of chemical constituents that could be adverse to beneficial uses of a waterbody.

The studies of Stenstrom and Strecker (1993a,b), Kerri *et al.* (1985) and Racin *et al.*(1982) provide information on the concentration of chemical constituents in highway runoff in California and especially Southern California. Caltrans Districts 8 and 12 are responsible for stormwater management for Caltrans highways in the Santa Ana region. Caltrans (1995) has developed a stormwater management plan for freeways and highways in this region. This plan includes data on the composition of highway runoff for several storms. These data can be used to some extent to estimate the concentrations of some constituents in ETC runoff. The Al-Kazily *et al.* (1995) report to Caltrans, in addition to discussing the various components of a stormwater runoff monitoring program also provides Caltrans data on the amounts of some chemical constituents in runoff from Caltrans highways. As with other studies on the chemical characteristics of highway runoff, this type of data provides highly limited information on the potential impacts of the chemical constituents in the runoff on the beneficial uses of the waterbodies receiving the runoff.

Areas that should receive particular attention for full implementation of the evaluation monitoring program are situations where HSUA stormwater runoff from a particular area represent a major source of chemical constituents and/or pathogenic organism indicators to a "pristine" waterbody. If there is going to be an impact of some known or yet unidentified chemical constituent in HSUA stormwater runoff, it is likely to be in those areas where the waterbody receives stormwater runoff from non-urbanized, non-agricultural areas. The construction of a highway and/or the development of an urban area in a "pristine" area would introduce a variety of chemical constituents through stormwater runoff that could potentially have their greatest impact in such areas. The evaluation monitoring program specifically examined this issue for each of the waterbodies which receive ETC runoff. None of them would be considered "pristine" and unimpacted by similar runoff from already existing sources.

Another purpose in estimating the current total HSUA stormwater runoff to an area is to obtain a perspective on whether installing BMPs for a component of HSUA stormwater runoff will likely be effective in reducing any adverse impacts of HSUA stormwater runoff-derived constituents on the receiving waters for the runoff. It is for this reason that this evaluation monitoring program for ETC runoff will be integrated into the overall stormwater runoff water quality evaluation and management program of the region.

The specific approaches for applying evaluation monitoring for future ETC stormwater runoff BMP development and modifications are discussed in this section. Table 1 summarizes the approaches that have and will be used to develop BMPs for each type of water quality use impairment that is typically of concern in HSUA runoff. A discussion of each of the components listed in this table is presented in this section with particular reference to its application to ETC.

Background Information on the Characteristics of ETC Runoff and Receiving Waters.

The concentrations of conventional, potential pollutants in highway and street runoff are fairly well known from studies conducted throughout the United States, Southern

California and Orange County. It is possible to estimate, based on the paved areas, the amount of stormwater runoff-derived constituents that highways and streets will contribute to a particular waterbody. While this concentration information cannot be used to estimate waterbody impacts of the stormwater runoff, it is useful to develop such information since it can help guide the development of the evaluation monitoring program for assessing the impacts due to stormwater runoff from a particular part of the highway. While there are some national average values for the concentrations of chemical constituents in HSUA runoff and there are several sets of values for the chemical constituent concentrations in Southern California highway runoff, the data that Caltrans District 12 is obtaining for the chemical characteristics of the runoff from highways in

Table 1

Components of Evaluation Monitoring for ETC BMP Development

Overall approach: Find a real water quality beneficial use impairment that is due to ETC stormwater runoff and then control it to the Maximum Extent Possible (MEP) using BMPs.

Determination of Receiving Water Use Impairment

Examine the receiving waters for water quality use impairments.

Consider the following types of possible impairments:

Impairment of domestic water supply water quality

Aquatic life toxicity

Excessive bioaccumulation of hazardous chemicals

Sediment toxicity that impairs water quality

Eutrophication - excessive fertilization

Sanitary quality impairment of contact recreation and shellfish harvesting

Oil and grease accumulation

Significant dissolved oxygen depletion

Litter accumulation

Siltation-excessive sediment accumulation

Specific Approach for Each Type of Use Impairment

Domestic Water Supply Impairment

Examine the characteristics of the raw water quality for highway runoff derived chemicals.

Determine the role of ETC runoff as a contributor of the chemical of concern.

If ETC is a significant contributor of chemical, work with regulatory agencies to develop source control BMPs.

Aquatic Life Toxicity

Determine if runoff waters containing ETC runoff are toxic.

Determine if toxicity is due to constituents in ETC runoff.

If runoff toxicity at the point that it enters the waterbody of concern is due to ETC runoff, evaluate the extent and duration of toxicity in the receiving waters.

If runoff toxicity is determined to be significant, work with regulatory agencies in developing source control BMPs to control toxicity to MEP.

Bioaccumulation of Hazardous Chemicals

Determine if edible aquatic life tissue contains concentrations of hazardous chemicals that impair its use as food.

If excessive bioaccumulation occurs, determine the significance of ETC runoff as a source of the chemical causing excessive accumulation.

If the chemical of concern is derived from ETC runoff, work with regulatory agencies in developing source control BMPs.

Sediment Toxicity

Determine if sediments are sufficiently toxic to impair the beneficial uses of the runoff receiving waters.

If significant sediment toxicity exists, determine if it is due to ETC runoff.

If ETC is a significant source of sediment toxicity, work with the regulatory agencies in developing source control BMPs.

Eutrophication-Excessive Fertilization

Determine if excessive algal and/or aquatic weed growth occurs that impairs the uses of the receiving waters for ETC runoff.

Determine the limiting nutrient-condition controlling the maximum algal - aquatic plant impairment.

Determine the limiting nutrient sources for the waterbody with particular emphasis on the role of ETC as a relative source. Focus the evaluation monitoring program on available forms of the limiting nutrient.

If nutrient control from highway and other sources of runoff could reduce the excessive fertilization of the waterbody, develop limiting available nutrient control program for all potentially significant sources of the limiting nutrient.

Sanitary Quality Use Impairment

Determine if sanitary quality - fecal indicator organism use impairment of the contact recreation and shellfish harvesting is occurring in the waterbody of concern.

Determine if ETC is possibly a significant source of fecal indicator organisms that are impairing the use of the waterbody for recreation and/or shellfish harvesting.

If ETC is a significant source of fecal indicator organisms at the point of concern, then work with the regulatory agencies to control the fecal indicator organism derived from the ETC.

Oil and Grease Accumulation

Determine if significant oil and grease accumulation is occurring in the receiving

waters for ETC runoff.

Develop increased water quality inlet control of oil and grease as well as implement source control programs.

Dissolved Oxygen Depletion That Impairs Aquatic Life

Determine if excessive DO depletion occurs in the waterbody of concern.

If DO problems are occurring, determine the characteristics of the diel and spatial DO depletion to evaluate the cause of depletion during times of runoff and non-runoff.

Determine if ETC runoff is a significant contributor to the DO depletion.

Work with the regulatory agencies in developing a program to control the input of DO depleting substances from ETC .

Litter Accumulation

Inspect the receiving waters for ETC runoff for highway-derived litter.

If highway-derived litter is impairing the beneficial uses of the waterbody, improve litter pickup and expand public education programs devoted to not littering.

This evaluation monitoring program for management of ETC stormwater runoff impacts should be repeated at least once in each five-year NPDES permit cycle to detect new water quality problems that may develop as a result of new chemicals introduced into ETC runoff as well as incorporate information on new approaches for assessing water quality impacts of constituents.

At this time, the focus of the ETC BMP development program for

Upper Newport Bay will be on:

excessive algal growth

bioaccumulation

sanitary quality

aquatic life and sediment toxicity

litter and oil/grease accumulation

For the Santa Ana River:

domestic water supply water quality

oil/grease and litter accumulation

For Santiago Creek, Irvine Lake and Upper Peters Canyon Reservoir

no specific field evaluation programs are planned at this time. The results of the programs for the Santa Ana River and Upper Newport Bay will be used to guide the development of evaluation monitoring for Santiago Creek, Irvine Lake and Upper Peters Canyon Reservoir should significant water quality problems attributable to ETC runoff be found in the Santa Ana River and Upper Newport Bay.

Because of the lack of technically-valid, cost-effective structural BMPs for control - treatment of highway runoff, the focus of the BMP development program will be on source control for those constituents that are found to impair the beneficial uses of the receiving waters for ETC runoff.

Evaluation of Potential Adverse Impacts of ETC Runoff

Information on any factors, such as mixing of ETC runoff water with water derived from other sources before entering the waterbody of concern, passage through vegetative areas, natural or constructed detention basins, etc., that might influence the concentrations of constituents in the runoff between the point where it leaves the highway and where it enters the receiving waters where water quality is of concern, will be considered in evaluating the potential impacts of ETC-derived constituents.

It is important, however, not to confuse removal of particulate metals and organics which are non-toxic, non-available in some of these structures with potential improvements in receiving water water quality. While detention basins will remove some of the particulate matter in the runoff waters which has associated with it chemical constituents that are in some situations potential pollutants, such removal does not necessarily lead to improvements in water quality in the receiving waters for the runoff. As discussed by Lee and Jones-Lee (1996c), detention basins can, however, reduce the siltation of the receiving waters and therefore, if siltation (sediment accumulation) is a problem, help address this problem. It is not expected, however, that siltation of the receiving waters will be a problem associated with ETC runoff due to the erosion control programs that will be implemented and the low levels of suspended solids normally associated with highway runoff.

For all ETC sections, the concentrations of constituents in the ETC runoff will be significantly diluted below the concentrations in the ETC runoff at the edge of the highway by non-highway runoff before it reaches the Santa Ana River, Upper Newport Bay, etc. This dilution and other factors which would tend to modify the concentrations of constituents in the highway runoff from that present in ETC runoff will be considered in developing the specific study program for evaluating the impact of this runoff on receiving water water quality. For example, if ETC runoff-derived constituents will be significantly diluted by non-highway runoff before it reaches the waterbody of concern, then the potential impacts of these constituents on the receiving waters will be primarily manifested in areas close to the point where the runoff enters the receiving waters of water quality concern.

Another factor that has been considered in developing the evaluation monitoring program is the total amount of HSUA runoff that will enter the waterbody near where the ETC runoff enters the waterbody that would contribute chemical constituents and pathogenic indicator organisms to the waterbody of the same type and approximate original concentration in the runoff as they leave the paved surface of the ETC.

For example, in the case of the northern leg of the ETC, there are approximately 60 acres of ETC surface area contributing runoff to the Santa Ana River near Gypsum Canyon. However, SR 91 parallels the Santa Ana River and will also contribute the same kinds and amounts per unit area of constituents as the ETC. It is estimated that 345 acres of SR 91 will contribute the same kinds of constituents to the Santa Ana River as the 60 acres of the northern leg of the ETC. It will be important ultimately to be able to determine the relative contributions of each source of constituents that are found through investigating the water quality use impairments of the Santa Ana River to determine what fraction of the HSUA runoff-derived pollutants are contributed by the ETC. This information will put in perspective the magnitude of any water quality problem that is found in the receiving waters due to HSUA runoff that is derived from the ETC.

A similar situation exists for evaluating the impact of ETC-derived chemical constituents on the water quality of Upper Newport Bay. If ETC runoff contributes chemical constituents that have an adverse impact on the beneficial uses of Upper Newport Bay, then the same constituents will be derived to a much greater extent from the other highways and the large area of residential and commercial developments that drain stormwaters into Upper Newport Bay. Therefore, any program for BMP development for ETC runoff should be part of an area-wide program that is designed to address the water quality use impairments that are occurring in the waterbodies of concern from all of the highways and streets in the area that are contributing the constituents of concern. This is an important conclusion since it means that the management of ETC runoff will be part of a much larger HSUA runoff management program that will need to be implemented to manage HSUA runoff impacts on the beneficial uses of Upper Newport Bay.

Another important step in formulating the ETC site-specific evaluation monitoring program is the collection of background information that is pertinent to determining the water quality characteristics of the waterbody where ETC runoff enters it. Previous studies on water quality characteristics have been reviewed to determine, to the extent possible, the current water quality and the factors influencing this water quality. It is important to understand that water quality is being used in this BMP development program to describe water quality use impairments and not chemical characteristics.

As discussed herein and as is well documented in the literature cited in the references, in many cases it is difficult, if not impossible, to reliably directly relate the chemical characteristics of a waterbody to its water quality - use impairment. It is for this reason that site-specific receiving waterbody studies of the type that will be conducted as part of this program must be conducted to specifically determine whether elevated concentrations of constituents in ETC, as well as other HSUA runoff, are causing a significant adverse impact on the designated beneficial uses of the waterbody receiving the runoff.

Mixing of Runoff Waters with Receiving Waters

An important topic addressed in the development of the evaluation monitoring program is the mixing of ETC runoff with the receiving waters. For example, the runoff from the northern leg of ETC will enter the Santa Ana River near Gypsum Canyon and form a nearshore plume that may be carried considerable distances downstream before mixing of the ETC-derived constituents occurs with the upstream river waters. The distance that the ETC runoff water plume travels downstream will be a function of the Santa Ana River discharge with higher discharges tending to carry the ETC runoff as a somewhat distinct entity further downstream. The rate of mixing of the runoff waters with the receiving waters will affect the impact of the chemical constituents in the runoff waters on the beneficial uses of the receiving waters. It is therefore important to assess the characteristics of the mixing that occurs as a function of discharge to both runoff waters and receiving waters.

At the point where the drainage channels carrying ETC runoff enter the waterbodies of concern, there will be a plume of the runoff waters formed within the receiving waterbody. A key component of evaluation monitoring in determining whether toxic chemicals in the runoff waters cause aquatic life toxicity in the receiving waters is the determination of the characteristics of the runoff water plume within the receiving waterbody. The areal extent and rate of mixing - dilution will be major factors determining whether toxicity measured in the runoff waters causes a toxic effect on aquatic organisms in the receiving waters.

If the toxicity in the runoff waters is rapidly diluted in the receiving waters to non-toxic levels within a few hours, then the likelihood of runoff water toxicity significantly adversely impacting the beneficial uses of the receiving waters due to aquatic life toxicity is small. If, however, the mixing of the runoff water plume with receiving waters is slow and takes a day or more, then there is greater potential for toxicity, especially for those toxicants such as the organophosphorus pesticides, i.e. diazinon, which are rapid-acting toxicants.

The mixing of San Diego Creek water into Upper Newport Bay will be dependent on a variety of factors such as discharge, tide, wind, and suspended solids carried in the runoff waters. Further, since Upper Newport Bay is saline and will have a density greater than that of San Diego Creek waters, San Diego Creek waters will tend to form a lens on top of the Upper Newport Bay waters which will inhibit the mixing of the ETC-derived constituents in San Diego Creek water discharges with Upper Newport Bay waters. However, the suspended solid load in San Diego Creek waters will tend to increase the bulk density of these waters and, thereby, tend to promote mixing between San Diego Creek waters and Upper Newport Bay waters. Previous studies (US COE 1992) have shown that the mixing of San Diego Creek waters with Upper Newport Bay waters is highly dependent on tide stage. At high tide, the freshwater inputs to Upper Newport Bay from San Diego Creek tend to be held near the mouth of San Diego Creek. At low tide, San Diego Creek waters tend to penetrate much further into the bay.

At the time that the ETC evaluation monitoring program is implemented, site-specific field studies will need to be conducted of both the discharges of ETC runoff waters to the Santa Ana River and Upper Newport Bay in order to define the mixing characteristics of the runoff waters in the receiving waters. As discussed below, however, these studies would only be conducted if there is substantial reason to believe that ETC-derived constituents are having a significant adverse impact on the designated beneficial uses of the Santa Ana River and Upper Newport Bay due to aquatic life toxicity.

It has been found that the mixing of two waterbodies can be fairly readily traced through field measurement of parameters such as temperature, specific conductance, and turbidity. Further, it has been found that drogues (devices that move with the water at the average speed of the watermass) can be used to estimate travel time within the ETC runoff plume in the Santa Ana River. For shallow rivers, such as the Santa Ana River, oranges have been found to be highly effective drogues for estimating river velocity. By dumping several oranges in the ETC runoff at the point where it enters the river, it is possible to determine the average velocity and, to some extent, the degree of mixing.

For deeper waterbodies, drogues constructed of one meter square sheets of aluminum that are slotted so that they form a cross that are attached to a small float through high-strength fishing line, can effectively trace watermass movement at any depth in the receiving waters. The position and velocity of the drogues, as a function of time from release, can be estimated based on the use of surveying equipment, sextant, range finder, and anchored buoys or stakes in the receiving waters. Field measurements with submersible temperature and conductivity probes that can be hand-held while wading across a shallow stream or suspended from a boat can be used to identify the position of the runoff water plume. By making transects across the receiving waters at various locations downstream of the point of entry of the runoff waters where temperature and specific conductance are measured as a function of depth at various transect locations, it is possible to define the position of the discharge water plume. Under shallow water conditions, the location of the measurements can be defined by positioning stakes at known distances along the transect.

For deeper waterbodies, buoys located at specific points can be used to measure distance along a transect. Also, various types of surveying equipment, including rangefinders, can be used to determine the position at which the temperature and conductivity measurements are made. This approach can lead to the development of a map of the discharge plume. Figure 1 provides a diagramatic representation of the discharge plume and generalized aspects of sampling locations.

Measurements of conservative chemicals (sodium, chloride, calcium, magnesium and sulfate) as well as electrical conductivity and temperature in the river or bay waters and within the plumes carrying the ETC runoff, can be used to estimate the rate of dilution of the plume waters that is occurring. With knowledge of the background receiving water concentrations of these various parameters and the concentrations in the runoff waters, it is possible to determine how much of the runoff waters has mixed with the receiving waters. It is also possible to determine the residence times of organisms in the plume. As discussed herein, this residence time is important in developing the duration of exposure and the dilution of the runoff waters with receiving waters that should be used in the toxicity tests to evaluate whether toxicity measured in the runoff waters could be adverse to aquatic life in the receiving waters to significantly impair the beneficial uses of these waters.

The discharge water plume's characteristics will be influenced by the conditions in the receiving waters and, therefore, will have to be determined under several sets of conditions that could influence the impact of ETC runoff on the beneficial uses of the receiving waterbodies.

Identification of Water Quality Impairments

With few exceptions, any adverse impacts of potentially toxic chemicals present in ETC runoff waters will likely occur near where the runoff enters the receiving waters. In most cases, ETC runoff will directly enter drainage channels which convey ETC and other runoff to the waterbodies of concern, such as the Santa Ana River and Upper Newport Bay. These drainage channels are recognized as intermittent stormwater conveyance channels and are not areas where there is serious concern about water quality use impairment.

While one of the Santiago Creek designated beneficial uses in the region where the ETC crosses the creek below Irvine Dam is listed as aquatic life, that listing is inappropriate since much of the year Santiago Creek in this region is dry. Based on discussions with H. Smythe of the SARWQCB, it appears that the listing of Santiago Creek designated beneficial uses including aquatic life did not adequately consider that the creek has no aquatic life resources during much of the year due to the lack of flow. There is need to correct the aquatic life beneficial use designation for Santiago Creek below Irvine Dam to reflect the hydrologic conditions that exist in this region.

In planning the site-specific evaluation monitoring program, it is important to discern what, if any, water quality use impairments exist at the point where ETC runoff enters the waterbody and downstream that could be attributable to ETC runoff. Such an evaluation could help guide focusing the resources available on site-specific problems that could be related to ETC runoff. The typical water quality use impairment problems of concern are:

Domestic water supply surface or groundwater impairment

Aquatic life toxicity in the water column and sediments

Bioaccumulation of hazardous chemicals in aquatic organism tissue

Excessive fertilization - eutrophication

Dissolved oxygen depletion

Petroleum hydrocarbons - oil and grease

Sanitary quality that impacts contact recreation

Aquatic life carcinogens - abnormal organs

Litter and debris accumulation

Accumulation of sediment in the waterbody that impairs uses

A summary of some of the issues that need to be considered in evaluating water quality use impairments is presented below.

Eutrophication. In a number of situations, it will be fairly obvious that a particular type of problem is or is not present. If the waterbody does not experience excessive algal or weed growth, then there is no need to focus significant amounts of the evaluation monitoring resources on developing data designed to determine the role that ETC runoff is contributing to these problems.

If, however, the waterbody is experiencing excessive algal or weed growth which is impairing the recreational or other uses of the waterbody, then it becomes necessary to determine the role that nutrients (nitrogen and/or phosphorus compounds) play in causing the excessive fertilization. Site-specific studies would need to be conducted to determine which chemicals (nitrate - ammonia or soluble orthophosphate) are currently limiting algal biomass in the receiving waters for ETC runoff in the region where the excessive algal growths occur. Further, it will be necessary to determine the role that ETC runoff plays in contributing the limiting nutrient to the waterbody that leads to the eutrophication-related use impairment. Specific guidance on how to conduct studies of this type has been developed by Lee and Jones (1988a,b) and Jones and Lee (1982, 1986).

A review of the information available shows that Upper Newport Bay is experiencing excessive fertilization which has been attributed to nitrate input to the bay. Gerstenberg (undated), in a report on the Management Plan for the Upper Newport Bay Ecological Reserve, has summarized the information available on the excessive fertilization of Upper Newport Bay. He indicates that previous investigators (Marine Biological Consultants, 1980) have found that nitrate concentrations in Upper Newport Bay waters decreased to growth rate limiting concentrations during summer algal blooms. It appears, therefore, that nitrate is the key element controlling excessive fertilization of Upper Newport Bay. This nitrate is primarily derived from commercial nurseries and agricultural sources although there were significant amounts of nitrate derived from urban runoff (Smythe 1990). The specific sources of the urban area runoff nitrate were not determined.

Dissolved Oxygen Depletion. While low dissolved oxygen (DO) water quality use impairments would not likely be due to ETC runoff, if such use impairments are found in the receiving water for the runoff, then specific studies would be conducted to determine the origin of the chemical constituents that lead to the dissolved oxygen depletion. Such depletions can be caused by biochemical oxygen demand (BOD), algal and aquatic plant photosynthesis - respiration and chemical reactions between constituents in runoff waters or stirred into the water column during runoff events from the sediments and the dissolved oxygen in the bay waters and runoff waters.

In some situations, such as in shallow streams and bays, runoff waters will disturb the sediments sufficiently to release sufficient quantities of ferrous iron and sulfide into the water column to cause depletion of the DO. Both ferrous iron and sulfide react rapidly with dissolved oxygen in the neutral pH range where the reactions take a few minutes to an hour or so for completion. Algal and aquatic weed-caused depletions show a cyclic diel pattern related to photosynthesis and respiration. BOD-caused depletions are slow-acting, taking several days for significant exertion of the oxygen demand associated with the bacterial respiration due to the use of organics as a source of food.

By examining the location, pattern of development and the characteristics of the waterbody, it is possible to determine the cause of the dissolved oxygen depletion associated with a runoff event. In thermally or salinity stratified waterbodies, it is possible, especially during the summer months, that low DO waters near the bottom could be mixed into the water column associated with runoff events. This can result in a fish kill due to low DO and the toxicity of hydrogen sulfide and ammonia. It does not appear from the information available at this time that this problem occurs in Upper Newport Bay, although it will be important to determine whether such a problem could develop associated with the deeper waters that will occur in the bay after dredging of bay sediments takes place. If such a problem is found, it will be important to determine what role, if any, ETC runoff plays in contributing to it.

Bioaccumulation of Hazardous Chemicals. It is fairly straightforward to determine whether there is a water quality use impairment associated with bioaccumulatable chemicals. As discussed herein, this can only reliably be done through measurement of aquatic organism tissue residues. By selectively sampling non-migratory fish and other aquatic life in the vicinity of the runoff water discharge plume and downstream thereof, it is possible to determine whether there is a real use impairment of these waters due to excessive accumulation of potentially hazardous chemicals. The chemicals that are causing the greatest concern today are the chlorinated hydrocarbon pesticides such as DDT and its analogs, chlordane, PCBs, dioxins and mercury.

When the ETC evaluation monitoring program is implemented, if there are insufficient data to determine whether excessive bioaccumulation of hazardous chemicals is occurring in aquatic organisms in Upper Newport Bay waters that is impairing their use as food, then this group of chemicals as well as others that are determined to be potentially important in Upper Newport Bay will be analyzed in selected samples of fish and shellfish collected from the bay. It will be important to work with Fish and Game personnel and others in selecting the organisms that should be sampled and the location of the sampling.

If it is not possible to sample the resident non-migratory fish and shellfish, then caged fish and shellfish can be used to determine whether there are hazardous chemicals potentially bioaccumulating to sufficient levels to impair the beneficial uses of the waterbody. It is important, however, to ascertain whether there is a real bioaccumulation problem and not rely solely on the accumulation of chemicals within mussels, such as associated with the Mussel Watch program. It has been found (Salazar, 1995) that a variety of factors which are poorly understood influence the degree of accumulation of potentially hazardous chemicals within mussels. Therefore, it is not possible to use the results of caged fish and mussel studies to determine water quality use impairment.

However, the caged fish/shellfish studies can help determine the origin of the bioaccumulatable chemicals that are impairing the use of aquatic organism resources of a waterbody as a source of human food. As discussed herein, in addition to considering bioaccumulation impacts on human health, consideration must also be given to adverse impacts on wildlife that use aquatic organisms as food.

Tumors and Abnormal Aquatic Life Organs. As part of examining aquatic life for bioaccumulatable chemicals, the collected organisms should be examined by an expert for tumors within various organs to determine whether there are chemicals in the waterbody that are causing tumors or other organ abnormalities in aquatic life. Since not all laboratories have the expertise to conduct this type of analysis, it may be necessary to contract with individuals who have the expertise to perform this analysis.

Aquatic Life Toxicity. The one problem area that is more difficult to discern is chronic toxicity to aquatic life. Acute toxicity, which results in death of the organisms within a short time after a runoff event that is manifested in a fish kill, is readily detectable. However, chronic toxicity that impairs the health of an aquatic population through impacting reproduction, growth rates, etc. is more difficult to detect. It is for this reason that evaluation monitoring focuses a considerable part of its resources on determining whether the runoff waters from ETC are potentially adversely impacting the aquatic life-related beneficial uses of Upper Newport Bay.

Similar attention will be given to the Santa Ana River near the point where ETC runoff enters the river at the mouth of Gypsum Canyon. It has been found (Risk Sciences, 1993) that the aquatic life populations in that part of the Santa Ana River are limited by aquatic habitat. There appears to be no aquatic life population limitations based on toxic chemicals derived from upstream domestic wastewater sources and urban area and rural stormwater runoff as well as runoff from SR 91 which parallels the Santa Ana River in this region.

The focus on aquatic life toxicity is justified since one of the primary areas of concern in HSUA runoff is the elevated concentration of heavy metals and certain organics in the runoff above US EPA water quality criteria and state standards for chemicals that are potentially toxic to aquatic life. By screening the receiving waters for ETC stormwater runoff for aquatic life toxicity, it is possible to determine whether any of the potentially toxic chemicals are, in fact, toxic to a sufficient extent and duration in the receiving waters for the runoff to adversely impact the beneficial uses of the water. As discussed in Appendix A, aquatic life toxicity tests of the type used in this evaluation monitoring program have been found to be highly reliable in predicting biological impacts of wastewater discharges on receiving water biological communities. It is important, however, in conducting such toxicity tests to properly incorporate the aquatic organism duration of exposure toxicity dilution situation that occurs in the runoff waters upon entering receiving waters. This is done through the discharge plume characterization described herein.

In assessing whether toxicity present in runoff waters is adverse to the beneficial uses of receiving waters, it is necessary to determine the duration and extent of the persistence of the toxicity in the runoff waters in the receiving waters. This can be done by determining toxicity of the water along the drogue path at various time intervals in the runoff water discharge plume. The toxicity testing should be done using the short-term chronic toxicity test listed in the US EPA manuals (US EPA 1994a,b, 1995e).

The actual design of the toxicity sampling and measurement program will be highly dependent on the hydrodynamic characteristics of the runoff discharge plume. The overall objective is to assess toxicity in the discharge plume under conditions that approximate the conditions that aquatic organisms present in the discharge plume would experience. Ideally, the toxicity tests should be conducted in such a way as to mimic the duration of exposure discharge water dilution curve in the discharge plume. This would involve taking samples of the ambient waters and discharge waters and mixing these on a flow-through basis in proportions to the percent dilution time situation that occurs in the runoff water discharge plume. Since few laboratories are equipped to conduct such tests, it is proposed that a step-wise implementation of this approach be used in which various dilutions of the discharge plume with the receiving waters are tested where the toxicity manifested at various times that an organism entrained in the discharge plume would experience is assessed.

Before implementing the studies designed to evaluate the persistence and extent of toxicity in the runoff waters that could be adverse to the receiving waters beneficial uses, it will be important to determine whether the stormwater runoff waters at the point at which they enter the waterbody of concern are toxic. If there is no toxicity in the runoff waters entering the waterbody and no toxicity develops when the runoff waters are mixed with the receiving waters, then there is no need to do further studies designed to evaluate the potential significance of toxicity on waterbody water quality. Additional information is provided on this topic area is provided in subsequent sections.

While some stormwater quality "impact" studies include toxicity measurements, these measurements are made at the point of runoff from the area such as the paved surface of the highway. Under conditions where this runoff immediately enters the waterbody of concern, then such measurements are appropriate to determine whether there is any potential toxicity in the receiving waters associated with the runoff. Measurement of toxicity at the point where ETC runoff leaves the highway and enters a drainage way that conveys the runoff waters to the waterbody of concern would not reliably assess the impact of this toxicity in the receiving waters where there is water quality concern. Measurement of toxicity at the point of runoff from ETC could significantly under or over-estimate the toxicity of ETC-derived constituents in the receiving waters.

For both the northern leg of ETC as well as the southern portion of the East and West Legs, there is appreciable dilution - mixing of ETC runoff before it reaches either the Santa Ana River or Upper Newport Bay. There would be significant dilution of ETC-derived toxic constituents due to mixing with waters derived from other sources. There also could be a situation where ETC runoff is not toxic at the point of discharge from the highway but, in combination with constituents from other sources, becomes toxic through additive or synergistic effects. It is for this reason that the evaluation monitoring program focuses on whether there is toxicity of sufficient potential magnitude at the point at which the ETC, as well as other area runoff that mixes with ETC runoff, enters the waterbody of concern.

For those situations in which there is toxicity in the ETC runoff at the point that it enters the Santa Ana River or Upper Newport Bay, it is suggested that samples should be taken near the origin before any significant dilution of the discharge plume occurs at one hour, six hours and one day intervals down the drogue path. If toxicity is found after one day, then daily sampling should be conducted along the drogue path if the discharge plume is still identifiable. If the discharge plume has become well-mixed in the receiving waters, then the toxicity of the receiving waters in the vicinity of where the mixture of the discharge waters and the receiving waters is now located, should be assessed. Each of these samples should be tested for toxicity using the short-term chronic toxicity tests discussed herein. The results of these tests should be examined at one hour, six hours and daily to see what, if any, toxicity has occurred. Consideration should be given in these tests to whether latent toxicity is manifested in aquatic organisms even though the waters are no longer toxic.

Consideration must be given not only to the duration of exposure but also the dilution of the discharge plume with ambient waters that occurs in the plume. Of particular importance is the matching of the exposure conditions for each dilution condition that is tested with the exposure condition that occurs in the field. Consideration must be given to both planktonic organisms which have limited locomotive ability as well as nektonic organisms, such as larger fish, that have the ability to determine their location through swimming. Further, both avoidance and attraction to discharge plumes should be considered. Fish may find that foraging in the runoff waters near the discharge is desirable; however, those fish that have this ability to maintain their position at this location are usually the larger, adult fish that tend to be less sensitive to toxicants than the larval planktonic fish.

While it is unlikely from the information available at this time that runoff waters from the ETC as well as other highways and streets that is attributable to automobile sources will be significantly toxic in the receiving waters to impair the designated beneficial uses of these waters, there is the potential for toxicity derived from atmospheric transported agricultural chemicals which are in highway runoff due to precipitation runoff events and dust or fog-fall on the highway to cause toxicity in the receiving waters. Majewski and Capel (1995) have recently reviewed the information on the atmospheric transport of pesticides. They have found that precipitation frequently contains sufficient concentrations of pesticides that have the potential to be adverse to receiving waters for stormwater runoff.

There are limited data (Bailey et al., 1993) that indicate that toxic organophosphorus pesticides are present in San Diego Creek waters which could be potentially toxic to aquatic organisms in Upper Newport Bay. While these pesticides may be associated with highway runoff, they are not derived from vehicular traffic or from chemicals used in highway maintenance. This evaluation monitoring program will determine whether this type of problem does, in fact, occur and its water quality significance in Upper Newport Bay.

If such problems are found and it is determined that ETC as well as other HSUA runoff is an important mode of transport of the agriculturally-derived chemicals to the bay, then source control BMPs should be implemented to control these chemicals at the agricultural source so they are not transported to the highway and become part of the runoff waters from the highway.

Powell and Leyva (1994) have reported finding that some herbicides (simazine and diuron) used by Caltrans to control excessive weed growth in the highway right-of-way are present in runoff waters. No information, however, is available on the potential water quality significance of these chemicals in adversely impacting the beneficial uses of the receiving waters for the highway runoff. Assessment of toxicity at the point of highway runoff often greatly exaggerates the exposure conditions that aquatic life would experience due to runoff from ETC. By the time that the runoff from ETC reaches Upper Newport Bay, there will have been appreciable dilution of many of these chemicals with runoff water from other sources that may have reduced the toxicity to the point that there is little or no residual toxicity in the San Diego Creek discharge waters as it enters the bay.

Further, the mixing that would occur in the bay may be sufficiently rapid so that any residual toxicity due to Caltrans-derived herbicides used on the ETC right-of-way would be rapidly lost due to mixing with the bay waters. This evaluation monitoring program would determine whether Caltrans-used herbicides contribute significant toxicity to Upper Newport Bay as well as the Santa Ana River to be adverse to the beneficial uses of these waterbodies.

There may be situations similar to those experienced by the city of Sacramento where urban area stormwater runoff is less toxic than the river water into which the runoff enters. Under these conditions, ETC runoff would help contribute to the reduced impacts of the ambient water toxicity on the beneficial uses of the waterbodies. This situation can be readily identified through this evaluation monitoring program.

Domestic Water Supply. The impact of ETC runoff on domestic water supply water quality for the Santa Ana River system and in Santiago Creek involves evaluating whether there are constituents in the runoff that are through groundwater recharge and recovery impairing the use of the recovered waters for domestic water supply purposes. This evaluation can best be done through examining the detailed chemical analyses of recovered waters that are performed by the Orange County Water District (OCWD). If it is found that there are constituents in the recovered waters that appear to be derived to a considerable extent from HSUA runoff, then site-specific studies designed to determine the origin of these constituents for the waters that enter the Santa Ana River recharge basins would be conducted. Such a program can be used to determine whether there is need to implement a BMP to control this chemical in ETC runoff.

At this time, based on a review of the OCWD Santa Ana River water quality monitoring data, it does not appear that any problems of this type are occurring in the Santa Ana River or Santiago Creek that can be attributed to current HSUA runoff. There is no reason to believe that the operation of the ETC would change this situation. However, at some time in the future some new exotic chemical that is not now known to be adverse to domestic water supply water quality could be found in HSUA runoff, including ETC runoff. If this occurs, it will be important for Caltrans, as managers of the BMPs for the ETC, to work with the OCWD and others to determine the role ETC runoff, which contains this exotic chemical, plays in contributing to the water quality problem that the OCWD and the Serrano Water District are experiencing at that time.

Tracing the Cause of Water Quality Use Impairment to the ETC

Once a water quality use impairment has been identified in the receiving water for ETC runoff, studies should be initiated to determine the origin of the constituents that cause the use impairment. This typically will involve sampling the runoff waters at various locations from the receiving waters to the point of runoff from the ETC to determine whether the constituents and/or toxicity is traceable to ETC runoff. Usually, this type of forensic study will determine the specific source(s) of constituents that are responsible for the water quality use impairment. As discussed in Appendix A, it is possible through toxicity investigation evaluation (TIE) in many cases to determine the specific chemical responsible for the toxicity. In this situation, it would be possible to trace a specific chemical back to its source. However, it is important to recognize that the same chemical from various sources can have significantly different amounts of toxic forms and, therefore, any chemical tracing must be accompanied by toxicity measurements to be certain that the tracing does not lead to an erroneous conclusion on the significance of a source of a chemical by focusing on the inert forms of the chemical.

In the case of toxic chemicals, if the TIE studies conducted to determine the cause of toxicity in the receiving waters are not successful in identifying a specific chemical(s), then measurement of toxicity at various locations from the receiving waters back to the ETC can determine whether the constituents responsible for the receiving water toxicity are present in ETC runoff.

In the cases where toxicity is found in ETC runoff, the specific cause of which is not identified, it would be important to make toxicity measurements of any runoff waters from adjacent lands that enter ETC runoff conveyance systems such as from hillsides, as well as from the atmosphere. As discussed herein, the atmosphere has been found to be an important source of toxicity in runoff waters in Northern California and elsewhere due to the use of diazinon as a dormant spray in orchards (Connor, 1995).

The sampling locations of Upper Newport Bay tributaries, including ETC runoff, to determine the origin of specific constituents causing water quality problems will be selected after review of OCEMA monitoring data that has been collected over the past several years at the time that ETC becomes operational. Over the next four years before this program is implemented, considerable additional data will be developed on stormwater runoff characteristics that will be used to formulate the details of the specific monitoring program that will be undertaken at the time that ETC becomes operational. The selection of these sampling stations would be based on agreement between Caltrans, the SARWQCB and OCEMA.

By the time that the ETC evaluation monitoring program is to be implemented, OCEMA may have already implemented a significant part of this program as part of its revised stormwater quality monitoring and evaluation program. The information from these efforts will likely be valuable in planning the ETC evaluation monitoring program for Upper Newport Bay since by that time a much better understanding of real water quality use impairments and their causes will likely be available. Based on current information, the sampling stations should include San Diego Creek just above any backwater effects from Upper Newport Bay, the Santa Ana Delphi Channel near Upper Newport Bay, at several locations along the drogue path for the plume developed in the San Diego Creek discharge as it enters Upper Newport Bay and at several locations in mid-Upper Bay and down Upper Newport Bay toward Lower Bay. Samples should also be taken near shellfish beds and at beach areas where contact recreation occurs.

Application of Evaluation Monitoring to the Santa Ana River

Characteristics of Santa Ana River.

The SARWQCB (1995) divides the Santa Ana River into various reaches. Reach 2 of the Santa Ana River between 17th Street in Santa Ana and Prado Dam is the reach which receives ETC runoff. This report characterizes Reach 2 as having beneficial uses which include agricultural water supply; groundwater recharge; water contact recreation; non-contact recreation; warm freshwater habitat; groundwater recharge; wildlife habitat; and rare, threatened and endangered species. This reach of the river is excepted from direct municipal water supply use, and does not support cold water fisheries; preservation of biological habitats of special significance; and spawning, reproduction and development of fish and wildlife.

The SARWQCB (1995) characterizes Reach 2 of the Santa Ana River near Gypsum Canyon as deep in many places with some rocky substrate and rapid sections. It is stated to support a variety of organisms. Further, Santa Ana River flows are a significant source of groundwater recharge in the lower basin which provides domestic water supplies for more than 2 million people. The river flows account for more than 70% of the total recharge. Additional information on the water quality characteristics of the Santa Ana River in Reach 2 is provided in Risk Sciences reports (1992, 1993).

Characteristics of ETC that Contribute Runoff to the Santa Ana River

Table 2 presents the discharge analysis of the Lower Santa Ana River. As indicated, the total area of the ETC that will contribute runoff waters to the Santa Ana River through either Gypsum Canyon or Gypsum Draw is about 60 acres. The total watershed for the Santa Ana River at that point is 1.4 x 10^6 acres. With respect to flows within Gypsum Canyon, the ETC will contribute runoff waters from 49 acres compared to a total area contributing runoff of 3,430 acres. For Gypsum Draw, the ETC contributes runoff from 11 acres out of a total of 180 acres.

From the flow information provided in Table 2 under low to moderate flow return frequencies (Q2 and Q10), the flows from the ETC will be about 1% of the total flow from Gypsum Canyon and about 6% from Gypsum Draw. It is evident that to the extent that ETC contributes constituents in runoff waters that are unique to vehicular traffic, that these constituents will be significantly diluted by runoff from the Gypsum Draw and Gypsum Canyon watersheds before entering the Santa Ana River. This dilution will further significantly diminish any adverse impacts that these constituents may have on Santa Ana River water quality - beneficial uses.

As discussed herein, SR 91 parallels the Santa Ana River in the reach where Gypsum Canyon discharges ETC runoff to the river. It is estimated that between Prado Dam and the spreading basins the total drainage area is 35,993 acres. Of this about 7.8% is impervious (2,793 acres). The addition of ETC as a source of impervious area that contributes runoff to the Santa Ana River in this reach changes the total impervious area to about 2,864 acres of which the ETC represents about 2.5%. It is therefore evident that any adverse impacts of runoff from highways and streets that occur in the reach of the Santa Ana River that receives ETC runoff will be dominated by non-ETC sources.

The impact of ETC runoff on the water quality characteristics of the Santa Ana River will be highly dependent on the release of water from Prado Dam. Prado Dam is scheduled to be improved as a part of the Santa Ana River Mainstem Project for additional flood control. The flood protection capacity of the dam will be increased from a present 70 year event to an estimated 190 year event. For water surface elevations lower than elevation 490 NGVD (reservoir pool elevation), releases are normally made to accommodate downstream ground water recharge capabilities. For water surface elevations higher than elevation 490 NGVD, releases are minimum outflow of 50 cfs to 1,500 cfs (depending on pool elevation) to a future maximum of 30,000 cfs at the spillway crest corresponding to a reservoir pool elevation of 563 NGVD. Sustained releases above 2,500 cfs have historically caused severe invert degradation and damage to downstream habitat. The maximum current scheduled normal release is 5,000 cfs. Releases greater than 5,000 cfs would result from spillway flow. Once the Santa Ana River Mainstem project is completed (including improvements to the lower Santa Ana River), the maximum scheduled release would increase to 30,000 cfs. Sustained releases of up to 2,000 cfs from Prado Dam for several days after major storm events are not uncommon. The high flow releases from Prado Dam are significantly deleterious to maintaining suitable aquatic life habitat in the Santa Ana River in Reach 2. According to Risk Sciences (1993), the management of the Santa Ana River for flood control is significantly detrimental to the aquatic life resources of the Santa Ana River in Reach 2.

Table 2
Discharge Analysis
Lower Santa Ana River
(cubic feet per second)

Location	Q100	Q25	Q10	Q2	Atotal(ac)	Aetc(ac)
Gypsum Canyon	4,918	3,427	2,725	1.182	3.430	49
Gypsum Draw	534	372	294	128	180	11.3
Santa Ana River	35.000	10,000	4,700	800	1,475,840	60

Atotal(ac) = Total watershed area in acres
Aetc(ac) = ETC drainage area in acres

Aquatic Life Toxicity. While there are some aquatic life resources in the Santa Ana River, these resources have already been severely impacted by flood protection activities. It appears, however, that the input of constituents from upstream point and non-point sources, SR 91 stormwater runoff, as well as runoff from other highways and residential developments that drain into the river in the reach that could be impacted by ETC runoff, are not adversely impacting the aquatic life-related beneficial uses of Reach 2 (Risk Sciences, 1993). However, if subsequent studies find some now unknown or new adverse impact due to stormwater runoff from highways and streets, then as discussed herein, ETC will contribute less than 2.5% of the paved area runoff to the Santa Ana River in this reach. Any unidentified problems that might arise from the ETC's stormwater discharges would already be present in the river due to SR 91 stormwater runoff. The ETC is expected to divert some of the traffic that is currently using SR 91 from SR 91 to the ETC. Therefore the ETC will, because of the possibility of removal and especially transformations of ETC stormwater-derived constituents in the transport from the point where the runoff leaves the highway to the Santa Ana River, tend to be in the direction of reducing current impacts of SR 91 stormwater runoff on the river.

SARWQCB (1995) presents Resolution No. 94-1 which states as item 11 on page 2,

"Regional Board Resolution No. 92-10, adopted February 14, 1992, found that some of the national water quality criteria, including those for cadmium, copper and lead, are inappropriate for the middle Santa Ana River because the flows are dominated by reclaimed water, which provides and supports beneficial uses which would not otherwise exist."

Conclusion 12 of this Resolution states under item d., *"Existing levels of cadmium, copper and lead in the SAR* [Santa Ana River] *do not contribute to toxicity in the Santa Ana River."*

Page 4-9 of the SARWQCB (1995) Santa Ana River Water Quality Control Plan indicates that the Use Attainability Analysis (UAA) studies (Risk Sciences, 1993) involving measurement of toxicity in the Santa Ana River indicate that the site-specific water quality objective for cadmium based on US EPA national criteria is 1.7 mg/L. The UAA determined that 4 mg/L of cadmium in the river is safe and non-toxic. Similarly, for copper the site-specific objective is 18.2 mg/L; copper at 37 mg/L was found to be non-toxic. The lead site-specific objective value is 4.1 mg/L; lead at 28 mg/L was found to be non-toxic in Santa Ana River waters.

SARWQCB (1995) stated, *"There is also evidence that levels as much as 100% higher than those shown above do not result in chronic toxicity."* These results indicate that there is little need for concern about heavy metals, such as cadmium, copper and lead, in ETC runoff contributing to toxicity in the Santa Ana River.

The Risk Sciences (1993) UAA studies on the Santa Ana River waters found that the lead, cadmium and copper that has been contributed to the Santa Ana River from SR 91 as well as from other highway and street sources and other sources were non-toxic. It is therefore appropriate to conclude that the ETC's runoff contribution of lead, cadmium, and copper will not change this situation.

The Use Attainability Analysis found no toxicity in the reach of the river that would receive ETC runoff. Therefore, it is highly questionable whether there is need to do additional toxicity investigations as part of this evaluation monitoring program to determine whether the heavy metals in the ETC runoff would be adverse to the aquatic life resources of the Santa Ana River. These heavy metals are also not threats to domestic water supply through groundwater recharge and recovery. While the heavy metals were found to be non-toxic and there was no toxicity in the Santa Ana River in Reach 2 due to other constituents in the early 1990s when the UAA studies were conducted, it would be appropriate to determine whether conditions have changed in 1999 when the ETC becomes operational. At that time, the evaluation monitoring program could include some toxicity investigations as part of the ETC evaluation monitoring program.

As planned now based on the current information, at least one and likely two stormwater runoff toxicity assessment studies would be conducted during the first year of the ETC's operations. They would initially focus on determining whether toxicity was present in the waters that carry ETC runoff into the Santa Ana River at the point where the runoff waters enter the river. If toxicity is found at this point that is judged to be potentially significant with respect to impacts on aquatic life, then more detailed studies of the type described in this plan of the persistence of this toxicity within the river in the discharge plume and after mixing with the river water would be conducted.

These studies would likely take place during the second year of the implementation of this plan. If the discharge plume studies reveal that the toxicity found in the ETC discharge waters, which also contains runoff from other areas, is potentially significant to the aquatic life resources in the Santa Ana River based on the magnitude and persistence of the toxicity within the river, then specific studies would be initiated to determine the specific source and cause of the toxicity.

If aquatic life toxicity is judged to be significant in ETC runoff, then specific plume toxicity measurements would be made to determine whether ETC runoff is contributing to any aquatic life toxicity that exists in the Santa Ana River. By sampling runoff waters at various locations in Gypsum Canyon, it will be possible to determine whether the ETC is contributing toxicity - toxic components of significance to impair the beneficial uses of the Santa Ana River. Of particular importance would be to distinguish between toxic materials present in ETC runoff from those derived from other areas.

If significant toxicity is found in ETC runoff, then the specific origin of this toxicity would be investigated with particular reference to the role of atmospheric deposition of pesticides and other non-vehicular traffic-related constituents as a source of the toxicity. If it is concluded that the toxicity is associated with emissions - releases from vehicular traffic, then studies would be initiated to determine the specific cause of the toxicity, i.e. such as exhaust emissions, materials derived from wear of automotive parts (tires, brake pads, etc.), and release of petroleum hydrocarbons, etc.

Once the specific cause of the toxicity is known, then site-specific source control efforts would be initiated to control this toxicity at the source. It is important to emphasize, however, that this type of program would not be initiated unless it is found that any toxicity in ETC runoff is, in fact, having a significant adverse impact on the designated beneficial uses of the Santa Ana River downstream of where ETC runoff enters the river through Gypsum Canyon. Further, these studies would not be done solely for ETC purposes since exactly the same problems would be occurring for other Caltrans highways and OCEMA managed highway and street stormwater runoff. The ETC studies would, therefore, be part of a coordinated effort to evaluate and manage any water quality problems that are found to be due to vehicular traffic emissions.

These types of studies would be conducted at least once in every five year NPDES permit period to determine whether a new toxicant has been introduced into the runoff waters as well as to consider new information which indicates that adverse effects of toxicity not previously recognized are occurring.

Sediment Toxicity. Sediment aquatic life toxicity does not appear to be a significant problem in the Santa Ana River that would be influenced in any way by ETC runoff. While there may be sediment toxicity in the Santa Ana River, this would be primarily due to a variety of factors that have nothing to do with highway and street runoff, such as residual constituents in domestic, commercial and industrial wastewaters and non-point discharges from agricultural and other rural lands. It is, therefore, planned that no work would be done to evaluate whether ETC runoff would be a contributor to Santa Ana River sediment toxicity problems if such problems exist.

As with other water quality parameters of this type, the need to conduct sediment toxicity studies as part of the evaluation monitoring program would be evaluated by Caltrans, OCEMA, and the SARWQCB in order to determine whether at the time that the ETC becomes operational that there is need for such studies associated with ETC runoff. If the regulatory agencies conclude that such work should be done, then it would be incorporated into this evaluation monitoring program.

Bioaccumulation of Hazardous Chemicals. If information does not exist at the time of implementation of this program, fish should be taken from the Santa Ana River to determine if excessive concentrations of bioaccumulatable chemicals are present in their tissue. The UAA studies (Risk Sciences, 1993) found no problems of this type in Reach 2 of the Santa Ana River. If bioaccumulation studies are conducted in the future, then the aquatic organism organs should be examined for tumors and other abnormal conditions. Caltrans, the SARWQCB and the OCEMA would be contacted for input relative to the bioaccumulation sampling program if such a program is implemented. Half a dozen to a dozen fish collected below Prado Dam should provide a sufficient database to determine whether excessive bioaccumulation is occurring in these organisms' tissue. The actual number of fish that need to be taken will be dependent on the variability of the tissue residue levels. If the initial sampling of the fish from the river shows that the concentrations of potentially hazardous chemicals that are near or above hazardous levels are highly variable, then additional sampling of fish will need to be conducted to reliably assess the potential threat that bioaccumulatable chemicals represent to the use of Santa Ana River aquatic organisms as food.

If excessive bioaccumulation of potentially hazardous chemicals is found that is believed to be due to current discharges, then caged fish and/or freshwater mussels should be positioned in the river at various locations above, at and downstream of the Gypsum Canyon stormwater input to determine whether runoff from Gypsum Canyon is a source of the excessive chemicals within the aquatic organism tissue. It may also be necessary to conduct bioaccumulation studies using US EPA/COE (1991) procedures or their freshwater equivalent (US EPA/COE, 1996) in which runoff waters are collected and aquatic organisms are exposed under laboratory conditions to the constituents in these waters.

While such testing procedures cannot be used to indicate the magnitude of bioaccumulation that will occur under field conditions, they are indicative of whether there is potential for bioaccumulation to be a problem in the receiving waters for the runoff. ETC runoff waters will be rapidly diluted in the receiving waters which will cause laboratory studies to significantly over-estimate the potential for excessive bioaccumulation to occur in the receiving waters.

Since a specific chemical is involved, it would be possible to sample ETC runoff, as well as runoff from other sources, to determine the origin of the chemical that is responsible for the excessive bioaccumulation. It is important, however, to not assume that all sources of a chemical have equal potential to contribute bioaccumulatable forms of chemicals to the same degree for the same concentrations in the runoff waters. It is well known that the specific forms of a chemical significantly influence the availability of chemical constituents to aquatic organisms that lead to excessive bioaccumulation.

As with toxicity, the specific origin of the bioaccumulatable chemicals that lead to excessive bioaccumulation in the Santa Ana River would be conducted to determine whether these chemicals are derived from atmospheric, non-vehicular traffic sources or from releases from vehicles. Once the origin has been determined, then site-specific source control programs would be initiated to eliminate the excessive bioaccumulation that is occurring in Santa Ana River waters that is due to chemical constituents in ETC runoff to the maximum extent practicable. Since SR 91 runoff will be a much greater contributor of these chemicals than ETC runoff, any ETC bioaccumulatable source control program would be part of a larger program designed to control the hazardous chemicals of concern that are part of the runoff waters from highways and streets that enter the Santa Ana River.

If no excessive bioaccumulation is found, studies of this type would be conducted once in every five year NPDES permit period in order to detect the introduction of new hazardous chemicals into ETC runoff since the last time that the studies were conducted.

Domestic Water Supply Water Quality. The primary issue of concern is whether ETC runoff will cause groundwater quality problems for the OCWD's use of the Santa Ana River waters to recharge the aquifer underlying the Santa Ana River spreading basins. This can best be done through a cooperative effort with the OCWD, the SARWQCB, the California Department of Health Services (CA DHS), OCEMA and Caltrans to examine the OCWD's analytical data on its raw water characteristics at the point of recovery of the recharged groundwater as well as the point of recharge where the Santa Ana River water enters the spreading basins. Of particular concern would be constituents that exist in sufficient concentrations in the recovered groundwater to impair its use that are also high in the recharged Santa Ana River water that are derived to a significant extent from ETC runoff.

As discussed above, at this time, there are no known problems of this type that can be attributed to highway runoff. There is a possibility, however, that at some time in the future, now unknown problems due to the presence of existing regulated chemicals as well as problems due to some of the unregulated chemicals could be identified in the recharged Santa Ana River waters. It would not be the responsibility of the ETC evaluation monitoring program to try to identify new hazardous chemicals in highway runoff that through groundwater recharge and recovery represent threats to water supply water quality. This information would be provided through state and national studies that evolve from ongoing research on the presence of new hazardous chemicals in domestic water supplies.

The sa types of water. In making these measurements, it will be important to consider salinity effects on the test organisms. It may be necessary to use marine test organisms for some of these tests.

If potentially significant toxicity is found in San Diego Creek runoff water, then studies will be conducted to determine if ETC runoff is the cause or a contributor to this toxicity. By measuring toxicity in ETC runoff waters, as well as in the runoff waters from other areas that enter the drainage channel conveying ETC runoff, it will be possible to determine whether ETC runoff is a potentially significant source of the toxicity that is found at the point where San Diego Creek enters Upper Newport Bay. To evaluate synergistic and additive effects, mixtures of ETC runoff and bay waters will be tested for toxicity to fathead minnow larvae and *Ceriodaphnia*. Initially, it is suggested that mixtures of San Diego Creek waters and Upper Newport Bay waters be tested at 25/75, 50/50 and 75/25 percent ratios.

Because of the potential importance of atmospheric transport of agricultural chemicals to the ETC which could cause toxicity in ETC runoff waters, it would be appropriate to measure toxicity in rainfall, dust fall, and fog fall onto ETC surfaces as well as nearby areas which would not be directly significantly impacted by vehicular traffic. Such measurements would be made only if ETC runoff appears to be a significant contributor to toxicity in Upper Newport Bay.

If it is found that the ETC runoff-associated toxicity is due to chemicals added to the ETC by atmospheric transport from agricultural or other sources, then there is no need to do further work on evaluating ETC runoff toxicity impacts on the beneficial uses of Upper Newport Bay from the perspective of developing a BMP to control stormwater runoff toxicity from the ETC. The BMP would be one of source control in which the regulatory agencies develop programs to control the toxicity of ETC runoff that is derived from agricultural sources. The development of these programs would not necessarily be the responsibility of Caltrans since the cause of this toxicity would not be due to vehicular traffic.

It is important to understand that just because toxicity is found in the undiluted San Diego Creek waters or in the mixtures of San Diego Creek waters with Upper Newport Bay waters, this does not mean that the toxicity of the runoff waters will be adverse to the aquatic life-related beneficial uses of Upper Newport Bay. The conditions of the toxicity tests which involve about a week-long exposure of the test organisms significantly over-estimate the toxicity that will be encountered in the receiving waters especially for slow-acting toxicants. It is for this reason that the follow-on studies involving characterizing the runoff water mixing plume-associated toxicity would be conducted to evaluate whether the runoff water toxicity is of potential significance to Upper Newport Bay's designated beneficial uses.

If no toxicity is found at the point where the San Diego Creek waters enter Upper Newport Bay, then there is no need to pursue toxicity as a possible cause of water quality use impairment in Upper Newport Bay due to the ETC and, for that matter, other sources of runoff water. Under these conditions, the toxicity runoff water evaluation program at the point where the runoff waters enter Upper Newport Bay would be re-conducted once in every five year NPDES permit period to determine if a new toxicant has been introduced into the ETC runoff.

If potentially significant toxicity that could be attributed in part to toxicants derived from ETC runoff is found at the point where San Diego Creek enters Upper Newport Bay, then there would be need to measure toxicity in samples taken along the drogue path of the San Diego Creek water plume. As discussed herein, this information would be used to evaluate whether the toxicity present in the San Diego Creek discharge waters that is attributable at least in part to ETC runoff could adversely impact the beneficial uses of Upper Newport Bay. The procedures that would be followed are similar to those described above for the Santa Ana River toxicity investigations.

Bioaccumulation. There is information in previous study reports (Blodgett, 1989) which indicates excessive bioaccumulation of chemical constituents in Upper Newport Bay aquatic organisms. Since these studies were conducted a number of years ago, it is not clear whether these conditions still prevail today. Many coastal waterbodies and bays show excessive bioaccumulation of constituents that are derived from past discharges of chlorinated hydrocarbon pesticides and PCBs. These constituents are not now present in highway runoff, and therefore, the current problems associated with these types of situations would not be expected to be influenced by ETC runoff.

In determining whether there is need for field studies to evaluate whether ETC runoff is contributing hazardous chemicals that are or could be accumulating to excessive levels within aquatic life tissue, it will be important to review the information that is available at the time that the ETC becomes operational to determine whether it is likely that there are any chemicals in ETC runoff, such as mercury, chlorinated hydrocarbon pesticides, and PCBs, that would be contributing to excessive bioaccumulation problems in Upper Newport Bay aquatic life. If it is judged at the time that the ETC becomes operational that there is a potential for excessive bioaccumulation in Upper Newport Bay edible fish and shellfish, then Upper Newport Bay resident fish and shellfish would, if possible, be sampled to determine if excessive accumulation of chemicals is occurring in the tissue that impairs their use as food.

If such impairment is found, then studies will be conducted to determine the role of ETC runoff as a contributor of the chemicals that are causing the excessive accumulation. This will involve sampling for these chemicals during stormwater runoff events at various locations in San Diego Creek and the tributary channels (Peters Canyon Wash and Marshburn Channel) as well as ETC runoff to determine whether ETC runoff is a significant source of the chemicals that accumulate to excessive levels within the fish and other edible aquatic life tissue. From the information available now, the samples would be taken from ETC runoff at several locations that are representative of runoff conditions to Upper Newport Bay and at one or two locations in each of the channels as well as San Diego Creek. It is likely that some of the current OCEMA sampling stations would be used for this purpose.

As discussed herein, caged fish and shellfish would be used to isolate the specific sources of the hazardous chemicals that are bioaccumulating to excessive levels in Upper Newport Bay fish and shellfish. It is important to emphasize, however, that finding an increase in the concentration of a chemical in aquatic life tissue does not represent an impairment of use. The increase must be sufficient to represent a health hazard to those who use the organism as food. In addition to considering human health effects, the impacts on wildlife should also be considered. At this time, the US EPA Great Lakes Initiative Wildlife Criteria (US EPA, 1993a) represent a source of information on this topic.

As part of sampling aquatic organisms within Upper Newport Bay in the bioaccumulation studies, the organisms' tissue would be examined for tumors and other abnormal conditions. If such conditions are found, then attempts would be made to use caged organisms positioned at various locations within the bay and its tributaries to trace the origin of the chemicals responsible for the abnormal tissue. Also, studies would be conducted to try to determine the chemicals responsible for the abnormal tissue development.

This activity would be part of a much larger program that would be developed by OCEMA, the SARWQCB and the California Department of Fish and Game. While the ETC evaluation monitoring program might help to determine if such a problem exists, Caltrans would not undertake the follow-on studies as part of the ETC evaluation monitoring program. This approach is justified, based on the fact that if a problem of this type exists, the ETC's contribution to it will be small compared to other sources of highway and street runoff.

Sanitary Quality. There are reports of sanitary quality problems within shellfish and at beaches within Upper Newport Bay. The ETC, as well as all streets and highways that contribute runoff, will contribute fecal indicator organisms to Upper Newport Bay. The first phase of evaluating whether the ETC contribution is of significance will be to determine the potential significance of the fecal indicator organisms derived from ETC runoff versus the other sources of these same organisms for Upper Newport Bay and the points of water quality concern within the bay.

Preliminary evaluations will be made to determine whether there is any possibility that ETC runoff would contribute sufficient fecal indicator organisms to justify the initiation of site-specific field studies in Upper Newport Bay and its tributaries that receive ETC runoff. From the information available now, it appears highly unlikely that this would be the case. If such studies are judged to be needed, then sampling from the points of where sanitary quality use impairments are occurring (shellfish beds, beaches) would be conducted through the Upper Bay, San Diego Creek, Peters Canyon Wash, Marshburn Channel and other drainage channels, including ETC runoff in order to determine whether the estimated contributions of fecal indicator organisms to the sanitary quality problems are due to any significant extent to ETC runoff. If, as expected, ETC runoff is found to be an insignificant source of these organisms, then there would be no need to implement the sanitary quality component of the ETC evaluation monitoring program.

Sediment Toxicity. One of the areas of potential water quality use impairment that may need to be examined in Upper Newport Bay is whether the sediments of the bay contain sufficient aquatic life toxicity due to ETC runoff to warrant controlling constituents in the runoff in order to control the use impairment of the bay waters due to toxic chemicals in the sediments. The recently completed US EPA EMAP studies will provide information on whether sediment toxicity problems are now occurring in Upper Newport Bay. It is also understood that IRWD will be sampling sediments as part of its monitoring program associated with the discharge from its wetlands project. There also should be some sediment quality data collected as part of the proposed dredging of Upper Newport Bay which will provide additional information on the current sediment quality problems in the part of the bay sediments that will be dredged. By the time that the ETC evaluation monitoring program is implemented, considerable new information will be available that will help determine whether there is need for the ETC evaluation monitoring program to include sediment quality evaluations in Upper Newport Bay.

If such studies are deemed of potential importance, then a series of sediment samples would be taken along the predominant San Diego Creek discharge plume path and at any location where sediments from San Diego Creek discharges tend to accumulate to determine if aquatic life toxicity occurs in these sediments. If high levels of toxicity are found that are not attributable to low dissolved oxygen, ammonia, and hydrogen sulfide, then samples of sediments will be collected at various locations in San Diego Creek, as well as Peters Canyon Wash and Marshburn Channel, to determine the potential origin of the toxic constituents in the sediments. The toxicity of the sediments should be measured using the techniques referenced herein developed by the US EPA and the Corps of Engineers (US EPA/COE, 1991, 1994). Also by then, since this is an active area of US EPA research, new sediment quality toxicity assessment methodology will likely have been published that would be used in these studies.

If significant sediment toxicity is found in Upper Newport Bay that is potentially due to ETC runoff, then the particulate fraction of ETC runoff would also be sampled and measured for aquatic life toxicity using the standard procedures described in this guidance. If significant toxicity is found, then sediment TIE studies of the type described by Ankley *et al.* (1991) should be conducted to determine the specific cause of the toxicity.

Eutrophication. Excessive growths of algae are a well-known water quality use impairment of Upper Newport Bay. While this problem appears to be related to excessive nitrate input to Upper Newport Bay, at this time it appears that an understanding of the relative significance of the various nitrogen sources (each of the tributaries, atmosphere and specific sources within the tributaries) is not well developed. If this situation persists at the time that the ETC evaluation monitoring program is implemented, then the first step in implementing this program is the development of a nitrogen load evaluation in which the total algal available nitrogen load to the bay would be determined. In addition, the total algal available nitrogen load from each of the tributaries and for each tributary, the individual sources of nitrogen (HSUA runoff, agricultural drainage, atmosphere, urban runoff, etc.) to these tributaries would be determined.

This can be done fairly reliably based on nitrogen export coefficients developed for various types of land use. Rast and Lee (1983, 1984) have discussed the development and use of such coefficients. The data that have been collected by OCEMA, Caltrans and others will be used to determine the amounts of nitrate and ammonia (grams N/m^2/yr) derived from various types of land use in the Upper Newport Bay watershed. This information will be used to estimate the relative significance of various sources of nitrate for Upper Newport Bay, including the contributions that would be made by ETC runoff.

It will be important to evaluate whether nitrate is, in fact, limiting algal biomass in Upper Newport Bay. The approaches discussed by Lee and Jones (1988a) for determining limiting nutrients in eutrophication-related water quality problems can be used for this purpose. If there is a significant surplus of nitrate in Upper Newport Bay compared to that needed by the algae, then controlling the input by a small amount will likely have little or no effect on the algal-related water quality problems of the bay. There may be such a surplus of nitrate so that the algal biomass is limited by other constituents or conditions. This appears to be the condition during the part of the year, i.e. summer, when there would be little or no input of nitrate to Upper Newport Bay from ETC runoff. During the rainfall runoff period (winter, spring), it appears from the OCEMA (1994) data as well as the information provided by Gerstenberg (undated) that the nitrate concentrations in Upper Newport Bay are significantly surplus compared to algal needs so that the additional nitrate provided to Upper Newport Bay from ETC runoff during that time does not contribute to additional excessive algal growth. It is also important to understand that, at least for a considerable period of time, the operations of ETC will not significantly change the amount of nitrate entering Upper Newport Bay from highway runoff that is associated with vehicular traffic. The vehicular traffic on ETC will likely for many years be traffic that would normally have taken other highways that contribute their nitrate-associated runoff to Upper Newport Bay.

US COE (1992) indicates that the flushing time for Upper Newport Bay is on the order of 10 tidal cycles; therefore, nitrate added to the bay during certain times of the year would not necessarily result in algal growth at other times of the year. Part of the nitrate added to the bay during the winter and spring would be flushed through the bay before its is taken up by algae and, therefore, would not contribute to algal growth. Some of the nitrate, however, added to the bay would during the spring and summer contribute to algal growth which would result in some algal-associated nitrogen (organic nitrogen) which does accumulate to some extent in bay sediments. Most of the algae, however, would be flushed out of the bay by tidal action and runoff. Algae that accumulate in Upper Newport Bay sediments would be mineralized where most of the organic nitrogen would be converted to ammonia which can be used directly by algae or through nitrification reactions to nitrate which is also available for algal growth. It would be important to determine the specific sources of nitrogen that lead to the excessive algal growth during the time of the year when excessive algal growth is of importance in adversely impacting water quality in order to properly evaluate the role of ETC runoff as a contributor to excessive fertilization of Upper Newport Bay.

It is likely that the amount of nutrients (nitrate, etc.) from ETC runoff relative to other sources will be judged to be insignificant, and therefore, there will be no need to carry out intensive field studies devoted to the potential impacts of ETC runoff on eutrophication-related water quality use impairment of Upper Newport Bay. This evaluation can be confirmed at the time ETC becomes operational through consultation with the Regional Water Quality Control Board and OCEMA.

Siltation. The accumulation of silt - sediments in Upper Newport Bay is a serious water quality problem that impairs the uses of the bay. ETC runoff, however, is not expected to contribute to these problems since the small amount of suspended solids in this runoff would represent an insignificant additional load to the bay compared to other sources. However, this problem has been noted as extremely sensitive within the San Diego Creek watershed, and provisions have been made for BMP implementation as part of the post-construction stormwater runoff water quality program to control particulates for portions of the Corridor tributary to Upper Newport Bay.

Dissolved Oxygen Depletion. The shallow nature of Upper Newport Bay coupled with the high levels of photosynthesis that occurs in the bay waters would tend to reduce the magnitude of any dissolved oxygen depletion problems that might be associated with stormwater runoff from highways and streets into the bay. It is not anticipated that ETC runoff will be a factor in contributing to any dissolved oxygen depletion problems that may develop in the bay associated with its deepening due to dredging.

Other Water Quality Use Impairments. ETC runoff to Upper Newport Bay will contain some litter and oil and grease. It is doubtful, however, that the ETC runoff contribution of these materials to the bay will be significant compared to other sources such as the other highways and streets that drain into the bay. A visual inspection of ETC runoff, Peters Canyon Wash, Marshburn Channel, San Diego Creek and Upper Newport Bay in the vicinity of where San Diego Creek enters the bay will be conducted to determine if local problems near the point of discharge are occurring due to litter and oil and grease. Several BMPs will be implemented to control litter and oil and grease from the ETC. These BMPs are discussed in the post-construction stormwater quality program summary report.

There are no other known or suspected water quality problems that ETC stormwater runoff would be expected to cause in Upper Newport Bay. If such problems do become evident, then they would be investigated in a manner similar to those outlined for the known potential pollutants in ETC runoff discussed above.

Application of Evaluation Monitoring to Santiago Creek

Characteristics of Santiago Creek and Irvine Lake

SARWQCB (1995) lists Santiago Creek, Reach 1 below Irvine Lake beneficial uses as being municipal water supply; groundwater recharge; contact recreation, although access is prohibited by OCEMA; non-contact recreation; warm freshwater habitat; and wildlife habitat. While the warm freshwater habitat is listed as a beneficial use of this reach, this listing is inappropriate; warm freshwater habitat should be listed as an intermittent beneficial use rather than as a full-time use because of the lack of habitat - water.

SARWQCB (1995) lists Irvine Lake (Santiago Reservoir) beneficial uses as being municipal water supply; agricultural water supply; contact recreation; non-contact recreation; warm freshwater habitat; cold freshwater habitat; and wildlife habitat. This waterbody is a private put-and-take fishery that is maintained by stocking.

Characteristics of ETC that Contribute Runoff to Santiago Creek

The evaluation of ETC runoff on Santiago Creek watershed water quality focuses on two areas. One of these is the part of the ETC which drains into an arm of Irvine Lake. The other is the point at which the ETC crosses Santiago Creek below the Irvine Lake dam. For much of the year, the creek is dry at the point of crossing.

Santiago Creek Watershed

Santiago Creek has its headwaters in the Santa Ana Mountains. It flows northwestward through Santiago Canyon and then southwestward through the cities of Orange and Santa Ana into the Santa Ana River. Elevations in the basin range from 110 feet at the confluence with the Santa Ana River to 5,687 feet at Santiago Peak in the Santa Ana Mountains. Stream gradients range from 25 feet per mile in the lower reaches of Santiago Creek to 305 feet per mile in the upper reaches.

Santiago Creek - Upstream of Irvine Lake

Much of the Santiago Creek watershed upstream of Irvine Lake is in the Cleveland National Forest and will remain undeveloped. Steep mountain channels give way to Santiago Canyon, a relatively wide wash with significant riparian vegetation and a relatively mild gradient. Limestone Regional Park is also located in this watershed. The regional park will remain rural and include only minor recreational development.

A small portion of the ETC passes through this watershed (about 11 acres). ETC runoff is tributary to a natural ravine located west of Irvine Lake and upstream of Santiago Canyon Road. The natural ravine is populated by native grasses with no shrubs or tree canopy. The current use is cattle rangeland. Flow in the ravine passes beneath Santiago Canyon Road via a 36" CMP culvert. Some riparian vegetation is present near the lake where groundwater is near the surface.

Santiago Creek - Downstream of Irvine Lake

About 57 acres of ETC are directly tributary to Santiago Creek downstream of Irvine Lake. An additional 48 acres are tributary to Upper Peters Canyon Reservoir, which is tributary to Santiago Creek via Handy Creek.

Most of the area tributary to Santiago Creek from the ETC is within Blind Canyon. Blind Canyon is currently undeveloped, with steep canyon sides giving way to a narrow incised canyon bottom. The average slope in Blind Canyon is about 6%. The creek channel is comprised primarily of rock and rock materials. Vegetation in the area is grasses and low shrubs with a few scattered trees such as oaks.

Santiago Creek is an alluvial wash with little vegetation. The bed material is comprised of coarse grained sands, gravel and cobbles. Flow in the creek is ephemeral, which is generally dry through the summer months, and flow only during releases from Irvine Lake.

Table 4 provides a listing of discharges and associated watershed or drainage areas for the Santiago Creek watershed. About 11 acres of ETC area are tributary to Irvine Lake. It is estimated that within the entire watershed, there are currently about 2,000 acres of impervious area (this is given as the last column in Table 4). Downstream of Irvine Lake at the confluence of Santiago Creek with Blind Canyon, the total ETC area tributary to Santiago Creek is about 93 acres with an estimated existing impervious area of about 2,100 acres at this same point. No estimates are available for the future impervious area within this watershed, though it is expected to increase substantially since it is currently mostly undeveloped.

Table 4
Santiago Creek
Watershed Areas and Discharges
(cubic feet per second)

Location	Q100	Q25	Q10	Q2	Atotal	Aetc	Aimperv
At Irvine Lake	12,600	8.780	6,980	3,028	40,788	11	2,000
At Blind Canyon	14,600	10,174	8,088	3,509	49,424	93	2,100

$A_{Total(ac)}$ = Total area in acres
$A_{ETC(ac)}$ = ETC drainage area in acres
$A_{imperv(ac)}$ = Impervious area in acres

The primary use of Santiago Creek waters is recharge for domestic water supply purposes. Therefore, the same issues that will be addressed as part of the impact of ETC runoff on groundwater recharge in the Santa Ana River will apply to the Santiago Creek recharge basins. No special studies are planned for evaluating the impact of ETC runoff on Santiago Creek; instead, information derived from the studies on the impact of ETC runoff on water quality in the Santa Ana River will be used to evaluate the impact of ETC runoff on Santiago Creek.

If water quality problems are found in the Santa Ana River due to ETC runoff, then the evaluation monitoring program will be expanded to examine whether these same problems are occurring in Santiago Creek. It is important to emphasize that the problems of concern in Santiago Creek are groundwater recharge since aquatic life resources in Santiago Creek are controlled by the fact that the creek is dry much of the year.

Application of Evaluation Monitoring to Upper Peters Canyon Reservoir - Peters Canyon Regional Park

Characteristics of Upper Peters Canyon Reservoir

SARWQCB (1995) lists the beneficial uses of [Upper] Peters Canyon Reservoir as being agricultural water supply: contact recreation, although access is prohibited by Irvine Ranch Company; non-contact recreation; warm freshwater habitat; and wildlife habitat. This reservoir is excepted from being listed for municipal water supply. It is now under the jurisdiction and control of the County of Orange as a public park.

Approximately 48 acres of the ETC are tributary to the Upper Peters Canyon Reservoir within a watershed of about 830 acres. Much of the watershed is currently undeveloped and comprised of grasslands. West of Jamboree Road substantial residential development exists but is limited to about 60 acres.

Creeks tributary to Upper Peters Canyon Reservoir flow from the Santa Ana Mountains across alluvial washes that are subject to significant erosion. The upper tributaries are relatively steep and characterized by vertical to near vertical banks that exhibit block type failures during large runoff events. Tributaries near the lake in the vicinity of Jamboree Road are substantially different in nature. Several riparian mitigation projects have been completed in and near creek areas. Slopes are greatly reduced and streambeds are substantially widened with associated lower flow velocities and the aforementioned increase in riparian vegetation, which is substantially absent in the upstream areas.

Upper Peters Canyon Reservoir spills to Handy Creek during uncontrolled flood events. The reservoir has flood control capacity but is not operated as a flood control facility, but rather a passive recreation lake. Releases from the reservoir are tributary to the lower Peters Canyon flood control basin and ultimately Peters Canyon Wash. Water is only released to Peters Canyon Wash for lake maintenance purposes. Water is maintained in the Upper Reservoir on a year round basis. Water for the reservoir is supplied by Irvine Lake.

Currently there are two species of fish, largemouth bass and bluegill, present in the reservoir which is closed to public fishing. A biological assessment of the reservoir completed by MBA (1994) indicated that there was a generally low abundance of fish, and that the reservoir habitat is well suited for sunfish. The reservoir was last drained for maintenance in 1990.

The reservoir stratifies in the summer with the lower approximately 8 feet anaerobic until fall overturn. The lake is about 17 feet deep. Releases from the lake during the summer have a brownish color accompanied by the strong smell of hydrogen sulfide gas. These problems do not occur following fall overturn where withdrawal from the lower level of the lake through the outlet works provides relatively clear water.

Fishing is currently prohibited due to poor shoreline access and the concern that wildlife (such as waterfowl) and hillside wildlife habitat will be disturbed. Also, fishing was not addressed in the Interim Operations Plan approved for opening the park. Fishing could be added as a recreational activity in the future, especially if an agreement could be reached with a private operator. Some fish (such as largemouth bass) were illegally stocked in the lake but all but the most tolerant species are not expected to survive.

Summary of Evaluation Monitoring Program Implementation

Presented below is a summary of the assessment of the potential water quality impacts of ETC stormwater runoff on the beneficial uses of the receiving waters for this runoff.

Santa Ana River. The focus of the Santa Ana River water quality impact analysis will be on developing a cooperative working relationship with the OCWD, OCEMA, and the SARWQCB to periodically review the information available on chemical constituents in highway runoff that could impact a domestic water supply's water quality in a groundwater recharge - recovery project. In addition, consideration will be given to identifying water quality problems in the Santa Ana River associated with aquatic life toxicity, bioaccumulation of hazardous chemicals, and excessive growths of algae. From the information available at this time, it appears that there is limited likelihood of significant water quality problems due to ETC runoff on the beneficial uses of the Santa Ana River.

If aquatic life toxicity and bioaccumulation of chemicals in Santa Ana River aquatic life is determined to be of greater importance than is currently perceived, then site-specific studies will be conducted devoted to assessing whether aquatic life toxicity in the runoff waters is adversely affecting the aquatic life resources of the Santa Ana River and the uses of these resources as a source of human food through the bioaccumulation of hazardous chemicals.

Upper Newport Bay. While there are several significant water quality use impairments in Upper Newport Bay, it does not appear from the information available now that runoff from the ETC will in any way affect the magnitude of these problems. ETC will not change the total amount of vehicular-derived constituents that enters Upper Newport Bay. If there are highway and street-derived constituents that are adversely impacting Upper Newport Bay water quality, then the ETC contribution to these problems will be small to insignificant. The development of BMPs for ETC runoff would be part of a larger BMP development program that would control highway and street runoff impacts on water quality in Upper Newport Bay. Such a program would be based on BMPs focusing on source control rather than treatment of runoff waters since effective treatment of the constituents of potential concern would be cost prohibitive.

Other Waterbodies. No adverse impacts of ETC runoff are expected for any of the other waterbodies, such as Santiago Creek; therefore, there is no need to conduct evaluation monitoring field studies on the impact of ETC runoff on the beneficial uses of Santiago Creek, Irvine Lake and the Upper Peters Canyon Reservoir. If the studies on the other waterbodies reveal potential problems, then consideration will be given to whether these problems are occurring in the other waterbodies as well.

Reporting Procedures

As the data are generated from the stormwater runoff event, they will be examined as soon as possible to determine what, if any, unusual results are obtained that will require additional studies to be conducted in the near-term. Each of the stormwater runoff events studied will be written up as a report and reviewed by all participants in the evaluation monitoring program. Guidance has been provided herein on the interpretation of the data and the possible follow-on studies that would be needed should water quality problems be identified in the receiving waters for the stormwater runoff. Based on the review of the data as they are collected, determination would be made as to what, if any, changes should be made in future runoff studies to more cost-effectively address water quality use impairments associated with the ETC, as well as other highway and street runoff.

At the end of each year, an overall synthesis report will be developed which contains the individual stormwater runoff study reports as well as the information that was developed on the real water quality problems that are present in the receiving waters for the ETC runoff. Information will be provided on the current understanding of the cause of the water quality problems and the specific source(s) of the constituents responsible for these problems. Particular attention will be given to presenting information on the current understanding of the role that ETC stormwater runoff plays as a cause of the water quality problems in the receiving waters for the runoff. This type of comprehensive review can provide highly important guidance on how the evaluation monitoring program can be formulated to best use the funds available to define real water quality use impairments associated with ETC runoff that are of such significance as to cause the expenditure of funds for their control.

Further, this report will include a discussion of the potential BMPs that could be developed to manage the water quality use impairments associated with ETC runoff. Particular attention will be given to formulating source control BMPs that would prevent, or at least greatly minimize, the amount of constituents in ETC runoff that becomes part of the runoff from vehicular, as well as external sources such as atmospherically-derived agricultural chemicals.

The final section of this report will specifically address the additional studies that need to be conducted to better define the role of ETC runoff in adversely impacting the beneficial uses of the receiving waters for the runoff. While the focus of the report is on ETC runoff impacts, the annual report will also discuss these impacts in the context of similar impacts from other highways and streets that contribute runoff to the waterbodies of concern that are adversely impacted.

Prioritization of Resources

By the time that this program is implemented, considerable additional information will likely be available on the characteristics of the waterbodies as well as the characteristics of stormwater runoff from highways. This information will be factored into refining the evaluation monitoring program at that time. The funds available will be prioritized to address the most significant water quality problems that could be associated with ETC runoff.

Generally, based on the information available now, aquatic life toxicity and the bioaccumulation of potentially hazardous chemicals are the areas of greatest concern with respect to ETC runoff to Upper Newport Bay. Fish and shellfish tissue sampling from Upper Newport Bay will receive priority in plan implementation. Further, at least two storms per year will be examined with respect to the degree and persistence of aquatic life toxicity in the San Diego Creek plume as it enters Upper Newport Bay should there be evidence that ETC runoff is contributing significant aquatic life toxicity to Upper Newport Bay.

Evaluation of the Efficacy of BMPs

The typical approach used for evaluating whether a source control BMP is effective in controlling stormwater runoff impacts is to measure the percent removal of a constituent before and after the implementation of the BMP. For structural BMPs, such as detention basins, across-the-basin measurements are typically made to assess percent removal of constituents. While the focus is on the removal of chemicals to judge BMP efficacy, this approach is not necessarily technically valid. As discussed herein, there is often a poor relationship between the concentration of chemicals in runoff waters and the impact of these chemicals on the beneficial uses of a waterbody.

An example of this is the use of detention basins for removing particulate forms of heavy metals. Since the particulate forms of heavy metals are non-toxic, passing stormwater runoff through a detention basin for heavy metal removal is not a valid BMP. Also, measuring a percent removal of heavy metals across a detention basin is not a valid assessment of BMP efficacy.

BMP efficacy must be determined by changes in the beneficial uses of the waterbody receiving the stormwater runoff. The measurement of decreased chemical concentrations in the runoff waters can only be used to assess BMP efficacy if a direct link has been established between the measured concentrations and the impact of the concentrations on the receiving waters' beneficial uses. For aquatic life beneficial uses, this would be the numbers, types and characteristics of desirable forms of aquatic life.

The evaluation monitoring approach provides a direct, reliable measurement of BMP efficacy. Changes in the ambient water toxicity, decreases in the aquatic organism body burdens of bioaccumulated chemicals, improvements in the sanitary quality of the receiving waters at the location where sanitary quality is of concern, reduced litter, etc. are all direct measures of BMP efficacy.

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Reference as:"Lee, G. F. and Jones-Lee, A.,"Evaluation Monitoring for Stormwater Runoff Monitoring and BMP Development," Report of G. Fred Lee & Associates, El Macero, CA, 96pp (1996). "