TOTAL MAXIMUM DAILY LOAD (TMDL)

DIAZINON AND PESTICIDE-RELATED TOXICITY IN SAN FRANCISCO BAY AREA URBAN CREEKS

Preliminary Project Report

California Regional Water Quality Control Board
San Francisco Bay Region

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September 2002

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SUMMARY

This preliminary project report is an important milestone. It addresses 35 Bay Area urban creeks formally designated as impaired water bodies pursuant to Section 303(d) of the Federal Clean Water Act. It also addresses all other Bay Area urban creeks potentially impaired by pesticide-related toxicity. This report contains the results of efforts to date to develop the TMDL for diazinon and pesticide-related toxicity. Each section is briefly summarized below. Publication of this report provides an opportunity for stakeholders to provide feedback on technical TMDL issues and the preliminary implementation strategy.

PROBLEM STATEMENT

The evidence that pesticides impair water quality in Bay Area urban creeks is consistent and compelling:

- Urban creek water is often toxic to some aquatic organisms.
- This toxicity has been linked to the presence of pesticides such as diazinon.
- Substantial quantities of diazinon and other pesticides are applied throughout the Bay Area.
- Diazinon's physical properties allow it to move through the environment and enter urban creeks.
- Diazinon levels in urban creeks often exceed California Department of Fish and Game water quality criteria.

For these reasons, the narrative toxicity objectives of the Water Quality Control Plan, San Francisco Bay Basin (Region 2) are not met, and pesticide-related toxicity impairs Bay Area urban creeks.

SOURCE ASSESSMENT

The primary source of pesticides, including diazinon, in urban creeks is urban runoff discharged through storm drains. Pesticides are discharged with urban runoff as a result of being manufactured, formulated into products, and sold through distributors and retailers to businesses and individuals. These businesses and individuals apply pesticides for agricultural, structural pest control, landscape maintenance, and various other pest management purposes. Inappropriate pesticide handling practices may account for some of the diazinon in urban runoff, but legal applications in accordance with label instructions may be responsible for much of this diazinon.

Bay Area residents report that ants are their most common insect pest. They apply pesticides to manage ants and many other insects. Wettable powders and emulsifiable concentrates appear to be among the product formulations that pose the greatest risks to water quality. Impervious surfaces are among the application sites that pose the greatest

risks to water quality. Applications to plants and soil also pose substantial water quality risks. Applications of products sold over-the-counter are believed to be among the greatest contributors to the diazinon in urban runoff. Applications by structural pest control operators also contribute substantially. Professional landscape maintenance and agricultural applications are smaller contributors.

NUMERIC TARGETS

The numeric targets proposed for diazinon in Bay Area urban creeks are:

> *The four-day average concentration of diazinon in freshwater shall not exceed 50 ng/l more than once every three years on the average.*
>
> *The one-hour average concentration of diazinon in freshwater shall not exceed 80 ng/l more than once every three years on the average.*

The proposed numeric targets for pesticide-related toxicity are:

> *The number of toxic units in freshwater, as determined through standard laboratory tests, shall not exceed 1.0 TUa or 1.0 TUc more than once every three years on the average.*

These targets apply to the water in urban freshwater creeks throughout the Bay Area. Together, the proposed numeric targets complement each other to protect water quality. The diazinon concentration targets ensure that the pesticide primarily responsible for toxicity in Bay Area urban creeks will not be discharged at levels high enough to cause toxicity. The toxicity targets address potential interactions among multiple chemicals and environmental stressors.

LINKAGE ANALYSIS

The sources of diazinon and pesticide-related toxicity can be linked to the numeric targets proposed to protect the beneficial uses of Bay Area urban creeks. The initial environmental release occurs during pesticide applications. Pesticides are then transported in surface runoff to storm drains during rain or irrigation events. Storm drains discharge runoff into urban creeks. This conceptual pesticide transport model applies to all Bay Area urban creeks. A quantitative transport model developed for a representative watershed (Castro Valley Creek) supports the conceptual model.

ALLOCATION SCHEME

The "total maximum daily load" is allocated to one source: storm drains. The discharge from each storm drain must meet the numeric targets when it enters an urban creek. Many parties bear responsibility for the discharge of pesticides through storm drains. The implementation strategy addresses the roles of these parties.

PESTICIDE OVERSIGHT

The responsibility for protecting water quality lies with pesticide users and their suppliers (i.e., retailers, distributors, formulators, and manufacturers). A diverse array of agencies and organizations oversee various aspects of pesticide use. Each of these entities will play a role in implementing the diazinon and pesticide-related toxicity TMDL. Those with the broadest authorities include the U.S. Environmental Protection Agency and the California Environmental Protection Agency (including the Department of Pesticide Regulation and the Regional Board). Bay Area municipal storm water programs are responsible for storm drain discharges through NPDES permits, but they cannot prohibit or regulate the registration, sale, transportation, or use of pesticides.

IMPLEMENTATION STRATEGY

The over-arching strategy for reducing the effects of diazinon in urban runoff will be to avoid conventional pesticide uses that threaten water quality. Outreach will promote least toxic pest management methods, including “integrated pest management.” The strategy focuses on proactive regulation, education and outreach, and research and monitoring. The role of the Regional Board is to encourage, monitor, and enforce implementation activities, and to lead by example. Implementation of the strategy is expected to achieve the proposed numeric targets and protect aquatic life beneficial uses. Water quality monitoring will confirm that the strategy is working.

1. INTRODUCTION

The Federal Clean Water Act requires California to adopt and enforce water quality standards. The *Water Quality Control Plan, San Francisco Bay Basin (Region 2)* (Basin Plan) delineates these standards by identifying beneficial uses of the region's waters, numeric and narrative water quality objectives to protect those uses, and provisions to prevent degradation of existing water quality (San Francisco Bay RWQCB 1995). Section 303(d) of the Federal Clean Water Act requires states to compile a list of water bodies that do not meet water quality standards. In 1998, 35 Bay Area creeks were placed on this list of "impaired" water bodies because pesticide-related toxicity, and diazinon-related toxicity in particular, is threatening aquatic life in the creeks (SWRCB 1999).

Section 303(d) of the Federal Clean Water Act requires the preparation of "total maximum daily loads" (TMDLs) for impaired water bodies. The TMDL process involves defining the impairment problem, identifying pollutant sources contributing to the problem, developing numeric targets that can be used to track progress in attaining water quality standards, linking the sources to the numeric targets, and allocating pollutant loads among the sources. This analysis provides important information to guide the development of implementation plans to attain water quality objectives.

This preliminary project report is an important milestone. It addresses 35 Bay Area urban creeks formally designated as impaired water bodies pursuant to Section 303(d) of the Federal Clean Water Act. It also addresses all other Bay Area urban creeks potentially impaired by pesticide-related toxicity. It contains the results of efforts to date to develop the TMDL for diazinon and pesticide-related toxicity. Publication of this report provides an opportunity for stakeholders to provide feedback on technical TMDL issues and the preliminary implementation strategy to eliminate pesticide-related toxicity in Bay Area urban creeks. This TMDL process may result in a Basin Plan amendment.

2. PROBLEM STATEMENT

In the San Francisco Bay Area, 35 urban creeks have been designated as "impaired" pursuant to Section 303(d) of the Federal Clean Water Act as a result of diazinon concentrations and aquatic toxicity observed in representative creeks (SWRCB 1999). Table 2.1 lists the impaired creeks and the threatened beneficial uses of the creeks related to aquatic life. Pesticide-related toxicity threatens cold and warm freshwater habitat, fish migration and spawning, and rare and endangered species. Proposed changes to the list of impaired water bodies would bring the number of creeks formally recognized as impaired by diazinon to 37 (SWRCB 2002). Figure 2.1 illustrates the locations of all these creeks.

As discussed below, urban creeks are considered impaired because (1) water in some urban creeks has been shown to be toxic to certain zooplankton (i.e., *Ceriodaphnia dubia*) through standard toxicity tests; (2) follow-up tests have identified organophosphorus pesticides, including diazinon in particular, as the primary factor responsible for the observed toxicity; and (3) monitoring data for some urban creeks in the Bay Area show diazinon levels in excess of levels believed to be toxic. This report focuses primarily on diazinon because it is the pesticide most often associated with pesticide-related toxicity in urban creeks. Pesticide-related toxicity may not be associated with diazinon exclusively, however, particularly as efforts to address diazinon begin to be implemented. Therefore, portions of this report address pesticides more generally.

BACKGROUND INFORMATION ABOUT DIAZINON

Diazinon is a broad-spectrum pesticide used to control a variety of pests, as listed in Table 2.2. Organophosphorus pesticides like diazinon were introduced in the 1950's as alternatives to organochlorine pesticides, which were discovered to persist in the environment, accumulate in living tissues, concentrate at increasing levels in organisms high in the food web, and pose substantial hazards to human health and the environment. Compared to organochlorine pesticides, organophosphorus pesticides do not tend to accumulate for long periods in the environment or concentrate to an appreciable extent in living tissues.

Many organisms metabolize diazinon to form diazoxon, which mimics acetylcholine, the chemical many organisms use to transmit impulses between their nerve cells (Central Valley RWQCB 1993). Normally, the enzyme acetylcholinesterase breaks down the acetylcholine to end neural stimulation and allow new impulses to be transmitted. By strongly binding to acetylcholinesterase, however, diazoxon inhibits acetylcholinesterase's ability to control acetylcholine levels. The result is continuously excited nerve cells, followed by death (Baird 1995).

Diazinon decomposes through photolysis, hydrolysis, and biological degradation. The extent to which these processes affect the decomposition rate depends on environmental

TABLE 2.1
Urban Creeks on the 303(d) List Due to Diazinon

Urban Creek	COLD	WARM	MIGR	SPWN	RARE
	Relevant Beneficial Uses				
Alameda County					
Alameda Creek	E	E	E	E	
Arroyo de la Laguna	P	P	E	E	
Arroyo de las Positas[b]	E	E	E	E	
Arroyo del Valle	E		P	E	
Arroyo Hondo[a]	E	E		E	
Arroyo Mocho[b]	E	E	E	E	
San Leandro Creek	E	P	P	P	
San Lorenzo Creek	E	E	E	E	
Contra Costa County					
Mount Diablo Creek	E	E	E	E	
Pine Creek	E	E		E	
Pinole Creek	E	E	E	E	
Rodeo Creek		E		E	
San Pablo Creek		E	E	E	
Walnut Creek	E	E	E	E	
Wildcat Creek		E	E	E	
Marin County					
Arroyo Corte Madera del Presidio	E			E	
Corte Madera Creek	E	E	P	P	E
Coyote Creek	E	E			
Gallinas Creek	E	E			
Miller Creek	E	E	E	E	E
Novato Creek	P	P	P	P	E
San Antonio Creek	E	E	P	P	
San Rafael Creek	E	E			
San Mateo County					
San Mateo Creek	P			E	E
Santa Clara County					
Calabazas Creek	E	E			
Coyote Creek	E	E	E	E	E
Guadalupe River		E	P	P	
Los Gatos Creek	E	E	P	P	
Matadero Creek	E	E	E	E	
Permanente Creek	E			E	
San Felipe Creek	P	E		P	
San Francisquito Creek	E	E	E	E	
Saratoga Creek	E	E			
Stevens Creek	E	E	E	P	
Solano County					
Laurel Creek	E	E	E	E	
Ledgewood Creek	E	E	E	E	
Suisun Slough		E		E	
Sonoma County					
Petaluma River[c]	E	E	E	E	E

[a] Arroyo Hondo has been proposed to be removed from the list because it does not flow through an urban area.
[b] Arroyo de las Positas and Arroyo Mocho have been proposed to be added to the list.
[c] The Petaluma River been proposed to be added to the list, but although this report addresses the Petaluma River's urban pesticide sources, it does not address other potential pesticide sources, such as agriculture.

COLD Cold Freshwater Habitat—Water that supports cold-water ecosystems, including preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife (including invertebrates).
WARM Warm Freshwater Habitat—Water that supports warm water ecosystems including preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife (including invertebrates).
MIGR Fish Migration—Water that supports habitats necessary for migration, acclimatization between fresh water and salt water, and protection of aquatic organisms that are temporary inhabitants of waters within the region.
SPWN Fish Spawning—Water that supports high quality aquatic habitats suitable for reproduction and early fish development.
RARE Preservation of Rare and Endangered Species—Water that supports habitats necessary for rare, threatened, or endangered plant or animal species.
E Existing Beneficial Use
P Potential Beneficial Use
Source: San Francisco Bay RWQCB 1995; SWRCB 1999; SWRCB 2002.

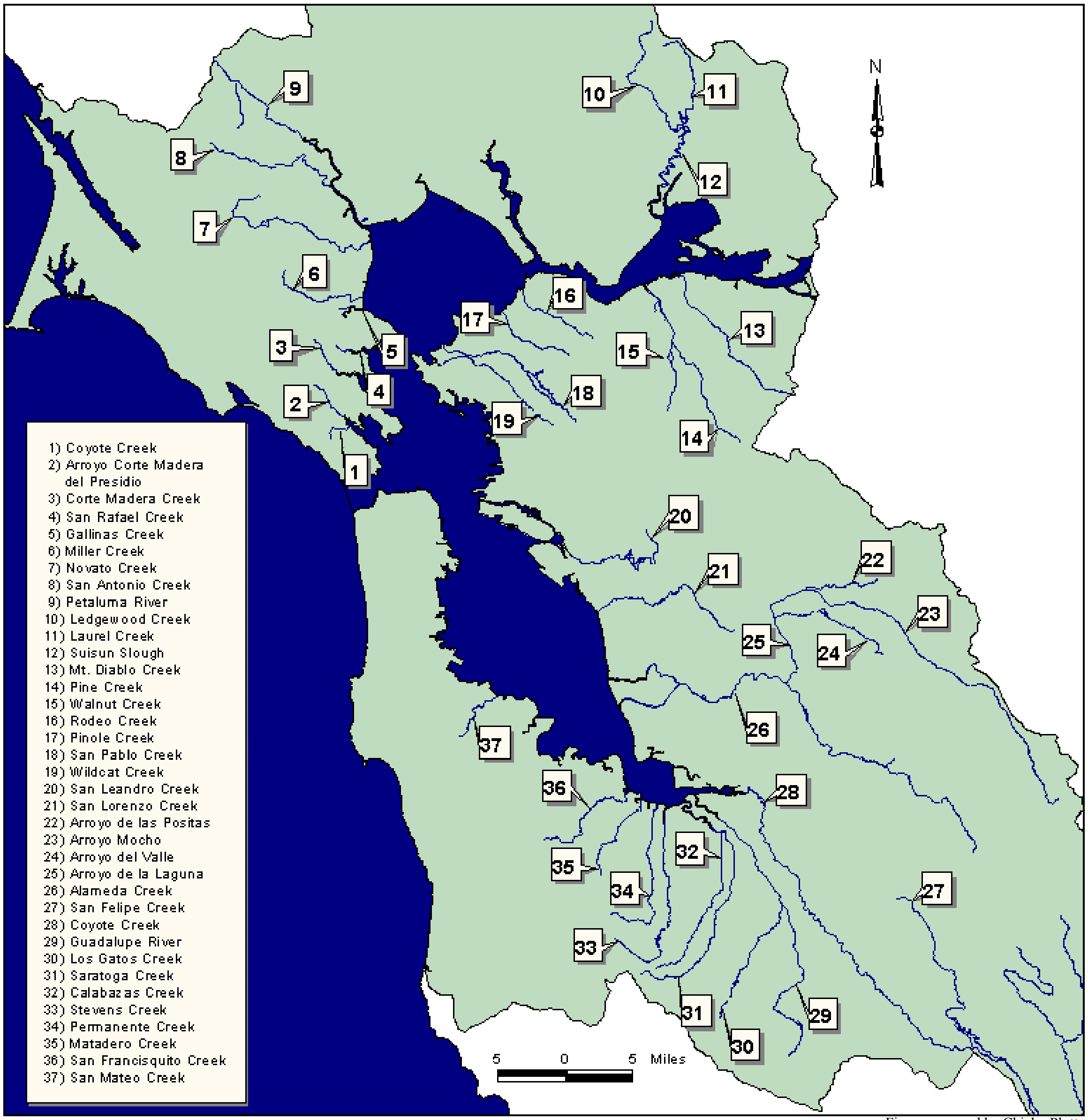

Figure prepared by Chieko Plotts

FIGURE 2.1
Urban Creeks on the 303(d) List Due to Diazinon*

*Arroyo Hondo has been proposed to be removed from the list because it is not an urban creek. Arroyo de las Positas and Arroyo Mocho have been proposed to be added to the list. The Petaluma River has been proposed to be added, but although this report addresses the Petaluma River's urban pesticide sources, it does not address other potential pesticide sources, such as agriculture.

conditions (e.g., lower pH tends to accelerate hydrolysis) (Novartis Crop Protection 1997). In soil, diazinon tends to decompose with a half-life of 2 to 6 weeks (Central Valley RWQCB 1993; Glotfelty et al. 1990; U.S. EPA 2000f). In water, diazinon decomposes with a half-life as short as 12 hours or as long as 6 months (Central Valley RWQCB 1993; U.S. EPA 2000e). A typical range for diazinon's half-life in surface water is between 1 and 3 weeks.

TABLE 2.2
Examples of Targeted Pests

Ants	Chiggers	Grasshoppers	Moths	Sow Bugs
Aphids	Cockroaches	Grubs	Pill Bugs	Thrips
Bees	Crickets	Hornets	Psyllids	Ticks
Beetles	Earwigs	Midges	Sawflies	Weevils
Borers	Fleas	Millipedes	Silverfish	Whiteflies
Butterflies	Flies	Mites	Skippers	Wireworms
Centipedes	Gnats	Mosquitoes	Spiders	Wasps

Source: Palo Alto 1996

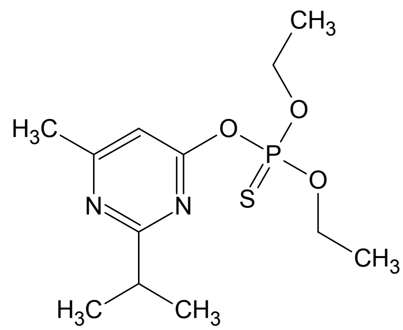

FIGURE 2.2
Chemical Structure of Diazinon

Diazinon's chemical formula is $C_{12}H_{21}N_2O_3PS$. Its technical name is *O,O*-diethyl *O*-2-isopropyl-4-methyl-6-pyrimidyl thiophosphate, and its chemical abstract number is 333-41-5. Figure 2.2 illustrates its chemical structure. At room temperature, diazinon is somewhat soluble in water; its solubility is about 40 milligrams per liter or 0.004%. Its octanol-water partition coefficient, K_{ow}, is about 2,000, and its organic carbon-water partition coefficient, K_{oc}, is about 1,000. Diazinon has a relatively low vapor pressure of 0.0001 torr (Novartis Crop Protection 1997).

DIAZINON TOXICITY TO AQUATIC LIFE

As a pesticide, diazinon is intended to kill pests, but it also kills other organisms. Although it is only moderately soluble in water, diazinon dissolved in water can be sufficiently concentrated to be toxic to some aquatic organisms, as indicated in Table 2.3. In the case of *Ceriodaphnia dubia* (a tiny crustacean sometimes called a "water flea"), the concentration of diazinon lethal to 50% of organisms within 48 hours of exposure (the 48-hour LC_{50}) is about 400 nanograms per liter (ng/l, parts per trillion) (U.S. EPA 2000e). The longer *Ceriodaphnia dubia* is exposed to diazinon, the lower the concentration needed to kill it. The 96-hour LC_{50} is about 340 ng/l (Bailey et al. 1997). The 7-day LC_{50} is roughly 100 ng/l (ACURCWP 1995a).

TABLE 2.3
Examples of Lethal Concentrations for Various Species

Species	Common Name	LC_{50} (ng/l)	Exposure (hours)
Bufo bufo japonicus	Frog (tadpole)	14,000,000	48
Pimephales promelas	Fathead minnow	7,700,000	96
Oncorhynchus clarkii	Cutthroat trout	2,200,000	96
Poecilia reticulata	Guppy	800,000	96
Orthretrum albistylum speciosum	Dragonfly (larvae)	140,000	48
Culex pipiens quinquefasciata	Mosquito	61,000	24
Pteronarcys californica	Stonefly	25,000	96
Cloeon dipterum	Mayfly (larvae)	7,800	48
Physa sp.	Snail	4,400	96
Daphnia magna	Water flea	800	48
Ceriodaphnia dubia	Water flea	400	48
Gammarus fasciatus	Amphipod	200	96

ng/l, nanograms per liter
Sources: CDFG 1994; Central Valley RWQCB 1993; CDFG 2000; U.S. EPA 2000e.

The California Department of Fish and Game has developed water quality criteria for diazinon using a U.S. Environmental Protection Agency (U.S. EPA) method and available toxicity data. The one-hour acute toxicity criterion is 80 ng/l. This value is an estimate of the highest concentration to which an aquatic community can be exposed briefly (i.e., one hour) without resulting in unacceptable effects. The four-day chronic toxicity criterion is 50 ng/l (CDFG 2000). This value is an estimate of the highest concentration to which an aquatic community can be exposed for longer periods (i.e., four days) without resulting in unacceptable effects. Using the same method (but somewhat different data and assumptions), U.S. EPA has developed a water quality criterion of 100 ng/l for both acute and chronic exposures (U.S. EPA 2000e). This value is intended to protect the vast majority of aquatic communities in the United States. These criteria are not to be exceeded more than once every three years.

Bay Area storm water agencies have tested urban creek and storm water samples for toxicity using a U.S. EPA protocol. U.S. EPA's "Whole Effluent Toxicity" test for freshwater determines whether samples are toxic to laboratory test species. It requires the use of three representative freshwater species: a zooplankton, such as *Ceriodaphnia dubia*; a phytoplankton, such as *Selenastrum capricornutum* (a single-celled green algae); and a fish, such as *Pimephales promelas* (the fathead minnow) (U.S. EPA 1993; U.S. EPA 1994). In accordance with the protocol, the responses of these laboratory test organisms are monitored and compared to those of control organisms. Assessing toxicity in this manner is consistent with the *Water Quality Control Plan, San Francisco Bay Basin (Region 2)* (Basin Plan) (San Francisco Bay RWQCB 1995).

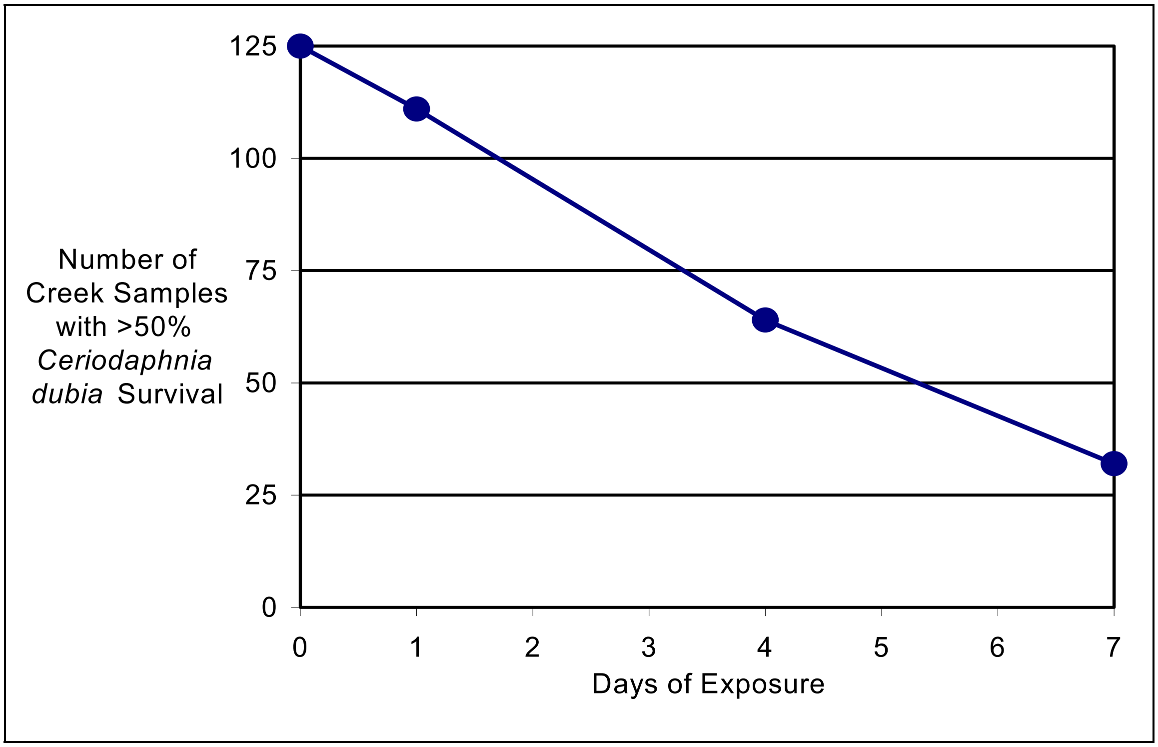

FIGURE 2.3
***Ceriodaphnia dubia* Survival in Bay Area Urban Creeks**

In the Bay Area, test results for storm water samples revealed *Ceriodaphnia dubia* to be the most sensitive of the three test species. As shown in Figure 2.3, of 125 samples collected from primarily Alameda County and Santa Clara County urban creeks, 74% were lethal to 50% of *Ceriodaphnia dubia* test organisms within 7 days. Within the first 24 hours of the tests, 11% of the samples were lethal to 50% of the test organisms.

Samples from residential and commercial storm drains were also lethal to *Ceriodaphnia dubia*. Of 14 samples, 93% were lethal to 50% of *Ceriodaphnia dubia* test organisms within 7 days. Within the first 24 hours of the tests, 50% of the samples were lethal to 50% of the test organisms (BASMAA 1996). Data collected elsewhere in Northern California have also demonstrated the toxicity of urban creek water to *Ceriodaphnia dubia*. For example, of 47 samples tested from Sacramento and Stockton urban creeks, 77% resulted in *Ceriodaphnia dubia* mortality within 72 hours (Bailey et al. 2000).

These results are meaningful because *Ceriodaphnia dubia* can be considered a surrogate for important creek organisms at the bottom of the food web. *Ceriodaphnia dubia* toxicity is believed to reliably predict or understate biological community responses. A U.S. EPA study concluded that when toxicity is present in surface water, as determined through standard toxicity test methods, ecological impact is also likely, as shown in Figure 2.4 (U.S. EPA 1999).

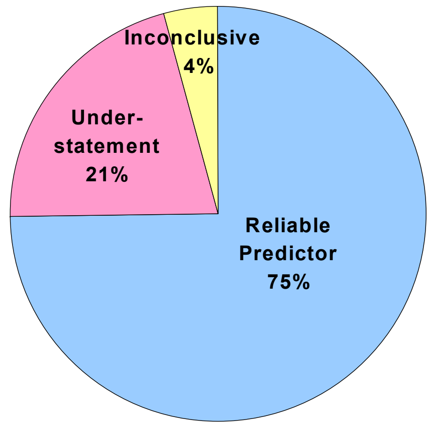

FIGURE 2.4
Reliability of Toxicity Tests in Predicting Biological Community Responses

To ascertain the cause of the toxicity in urban creeks, Toxicity Identification Evaluations have been undertaken in accordance with U.S. EPA protocols. A Toxicity Identification Evaluation is a three-phase process used to identify the chemical cause of toxicity. The first phase is to identify the type of chemical causing the toxicity. A toxic sample is subjected to a variety of chemical and physical procedures designed to remove certain classes of chemicals from the sample and thereby determine which is responsible for the toxicity. Having narrowed the cause of the toxicity to a class of chemicals, the second phase is to determine which chemical within the class is actually present in the sample at potentially toxic levels. The third phase is to confirm that the chemical actually causes the toxicity (e.g., by testing the sample for toxicity before and after selectively removing the chemical).

Toxic samples collected in Alameda County have been subjected to Toxicity Identification Evaluations using *Ceriodaphnia dubia*. One study involved sampling San Lorenzo Creek and, to a lesser extent, Alameda Creek. Toxicity Identification Evaluations were completed on four samples from a 1993 storm, four samples from a 1994 storm, and two samples collected following another small storm in 1994. The chemical cause of the toxicity was determined to be a neutral non-polar organic compound. Piperonyl butoxide, which blocks the metabolism of organophosphorus pesticides and thereby blocks their toxicity, was added to the test samples. Because the piperonyl butoxide decreased the toxicity of the samples, the cause of the toxicity was concluded to be an organophosphorus pesticide. Diazinon was detected in the samples at concentrations ranging from about 820 ng/l to 2,900 ng/l. These diazinon levels exceed the 48-hour LC_{50} for *Ceriodaphnia dubia*. Since diazinon was the primary pesticide in the samples and was present at potentially toxic levels, diazinon was concluded to be the organophosphorus pesticide responsible for the toxicity in San Lorenzo Creek and Alameda Creek (ACURCWP 1995a).

A similar study was conducted on water collected from Crandall Creek following a 1994 storm. That Toxicity Identification Evaluation identified diazinon as the source of the observed toxicity. The diazinon concentration in the sample was about 250 ng/l, a level slightly below the 96-hour LC_{50} of 300 ng/l estimated for *Ceriodaphnia dubia* during the same study (ACURCWP 1995b).

Toxicity Identification Evaluations completed elsewhere in California have also found that organophosphorus pesticides cause toxicity in urban creeks. In Sacramento and Stockton, for example, organophosphorus pesticides were determined to cause toxicity in four of five samples tested. When piperonyl butoxide was added to 14 other samples from Sacramento and Stockton urban creeks, toxicity was eliminated in 12 of them. In each case, diazinon concentrations were between 260 and 1,000 ng/l, levels high enough to account for the toxicity (Bailey et al. 2000).

DIAZINON CONCENTRATIONS IN URBAN CREEKS

According to California Department of Pesticide Regulation reports, an average of over 85,000 pounds of diazinon were applied in the Bay Area each year from 1995 to 2000 (CDPR 2001a; CDPR 2000a; CDPR 2000b; CDPR 1999a; CDPR 1999b; CDPR 1996). Unreported over-the-counter purchases in urban areas are believed to be about as high as reported applications (Alameda County 1997). In light of the evidence that diazinon causes toxicity in some Bay Area urban creeks, diazinon levels were measured in a larger number of Bay Area creeks. Following 1994 and 1995 winter storms, diazinon was found at concentrations ranging from 38 to 590 ng/l in creeks throughout the Bay Area, as shown in Table 2.4 (SWRCB et al. 1997). The median concentration was about 370 ng/l. These preliminary measurements spawned more extensive studies.

A study of Castro Valley Creek during the 1995-1996 rainy season measured diazinon concentrations following 12 storms. Diazinon was detected in all samples, and as shown in Figure 2.5, the mean concentration for each storm event ranged from 180 to 820 ng/l. The median concentration for a storm event was 310 ng/l. In some cases, values over 150 ng/l persisted for up to one week. The same study reported diazinon concentrations during periods of non-storm flows (during spring, when flows were less than 5 cubic feet per second) ranging from 110 to 760 ng/l, with a median of 420 ng/l. Samples collected during longer dry weather periods ranged from 35 to 220 ng/l, with a median of 80 ng/l (ACCWP and Alameda County 1997).

During the 1995 and 1996 dry seasons, diazinon was detected in 12 of 12 water samples collected from Castro Valley Creek. Concentrations ranged from 40 to 340 ng/l, with a median value of about 65 ng/l. Diazinon was detected in 16 of 18 water samples collected from Crandall Creek. The detection limit was 30 ng/l, and detected concentrations ranged from 58 to 442 ng/l. The median value was about 220 ng/l. Diazinon was detected in 8 of 9 samples collected at three inlets to Tule Pond in Fremont. The detection limit was 25 ng/l, and detected concentrations ranged from 80 to 3,000 ng/l. The median value was 300 ng/l (SWRCB et al. 1997). A study of 15 urban

TABLE 2.4
Diazinon in Bay Area Creeks, 1994 and 1995 Wet Season

Creek	Concentration (ng/l)
Crandall Creek	400
Rheem Creek	590
Walnut Creek	570
Codornices Creek	248
Dimond Creek	38
Castro Valley Creek	533
Strawberry Creek	162
Bockman Creek	397
San Pedro Creek	*
Adobe Creek	391
Barron Creek	165
Matadero Creek	130
San Francisquito Creek	74
Corte Madera Creek	*
Ignacio Creek	44
Belmont Creek	580
Calabazas Creek	343
Guadalupe Creek	143
Coyote Creek (Santa Clara County)	97
Napa River	*

ng/l, nanograms per liter
* The concentration was below the detection limit of 30 ng/l.
Source: SWRCB et al. 1997.

creeks throughout Alameda County involved collecting samples during the 1998 dry season. The samples were collected on Sunday afternoons, when gardening activity and pesticide applications were expected to be high. As shown in Table 2.5, diazinon was detected in 26 (44%) of 59 samples. The detection limit was 30 ng/l (ACCWP 1999a).

The presence of diazinon in urban creeks is not unique to the Bay Area. A study involving 231 samples collected from Sacramento and Stockton urban creeks during the 1994-1995 rainy season found that diazinon concentrations ranged from below the detection limit of 30 ng/l to as high as 1,500 ng/l. The median concentration was 210 ng/l (Bailey et al. 2000).

Diazinon concentrations in Bay Area urban creeks vary seasonally, declining during winter and increasing in spring. The Castro Valley Creek study found that changes in diazinon concentrations follow the seasonal diazinon use pattern. Diazinon applications drop during winter and rise in March, with the heaviest applications during summer and

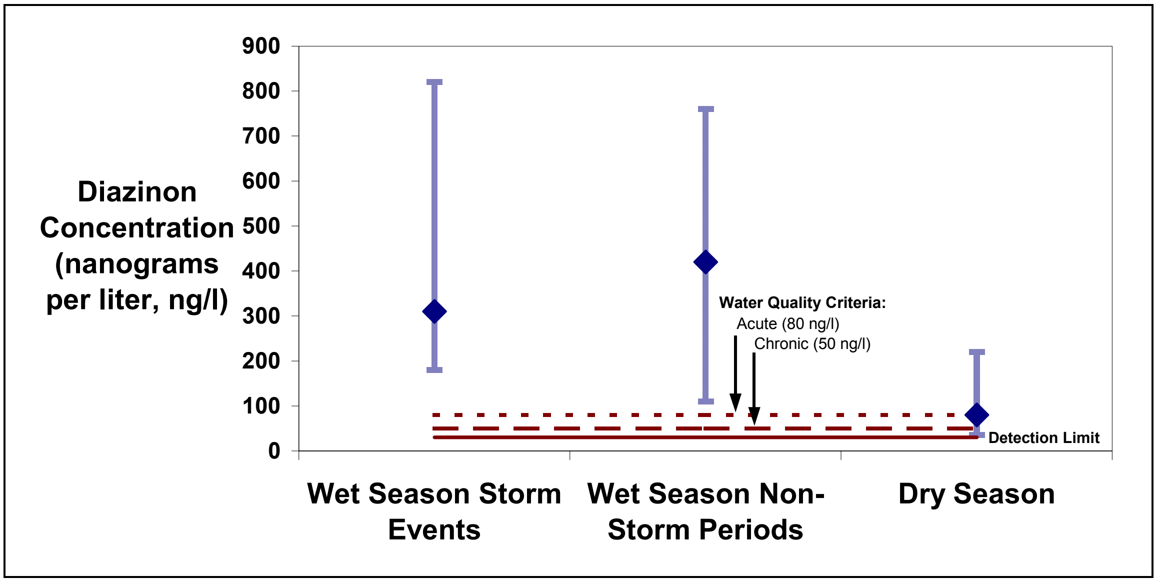

FIGURE 2.5
Diazinon Concentrations in Castro Valley Creek, 1995-1996

TABLE 2.5
Diazinon in Alameda County Creeks, 1998 Dry Season

Urban Creek	No. of Samples	No. of Detections*	Range of Detected Concentrations (ng/l)	Median Detected Concentration (ng/l)
Cerrito Creek	8	2	57 - 241	150
Codornices	2	0		
Strawberry Creek	2	0		
Glen Echo Creek	5	3	32 - 92	92
Sausal Creek	2	0		
Arroyo Viejo	2	0		
San Leandro Creek	5	0		
Castro Valley Creek	5	5	32 - 149	42
San Lorenzo Creek	1	1	37	37
Ward Creek	2	1	29	29
Alameda Creek	5	1	137	137
Arroyo de la Laguna	10	7	57 - 617	94
Agua Caliente	2	1	33	33
Agua Frio	2	1	82	82
Scott Creek	5	3	55 - 251	73

ng/l, nanograms per liter
* Detection limit = 30 ng/l
Source: ACCWP 1999a.

early fall. Diazinon concentrations in storm water were greater when no substantial precipitation preceded a storm; therefore, diazinon levels were highest in storm water associated with the first winter storms. Variations in diazinon concentrations appeared to follow one of two patterns during storm events. A peak concentration occurred early, followed by a substantial decline, or elevated concentrations remained relatively consistent throughout a storm. The early peak concentrations correspond to storms following periods without substantial precipitation. After storms ended, diazinon concentrations remained elevated, dropping by about one half within two days (ACCWP and Alameda County 1997).

Diazinon enters urban creeks from multiple sources. During dry weather, discharges are sporadic; pulses from different sources occur at different times. Water samples collected at the bottom of a watershed tend to average the effects of different pulses and their concentrations tend to be lower than the peaks observed upstream (ACCWP 1999b; ACCWP and Alameda County 1997).

WATER QUALITY OBJECTIVES AND LISTED CREEKS

The Basin Plan does not contain a numeric water quality objective for diazinon; however, it does contain the following narrative objectives applicable to diazinon-related toxicity in urban creeks (San Francisco Bay RWQCB 1995):

> *All waters shall be maintained free of toxic substances in concentrations that are lethal to or that produce other detrimental responses in aquatic organisms. Detrimental responses include, but are not limited to, decreased growth rate and decreased reproductive success of resident or indicator species. There shall be no acute toxicity in ambient waters….*
>
> *There shall be no chronic toxicity in ambient waters. Chronic toxicity is a detrimental biological effect on growth rate, reproduction, fertilization success, larval development, population abundance, community composition, or any other relevant measure of the health of an organism, population, or community….*

The toxicity data for Bay Area urban creeks suggest that these narrative water quality objectives are often not met. While samples collected from Bay Area creeks draining open space have not been toxic to *Ceriodaphnia dubia* (BASMAA 1996), many samples collected from urban areas have been lethal to *Ceriodaphnia dubia*. Toxicity Identification Evaluations have attributed the observed toxicity primarily to diazinon. Diazinon concentrations in urban creeks throughout the Bay Area are often within the range of those found to be lethal to *Ceriodaphnia dubia*. Diazinon levels also frequently exceed the California Department of Fish and Game's water quality criteria for diazinon. For these reasons, urban creeks are not considered to be free of toxic pesticides (e.g., diazinon) in concentrations that are lethal to aquatic organisms at the lower levels of the food web, and the narrative objectives of the Basin Plan are not met.

The availability of toxicity data varies among Bay Area urban creeks. In some cases, such as with Castro Valley Creek, San Lorenzo Creek, and some other creeks in Alameda County, a wealth of information is available. In other cases, only a few diazinon measurements have been made. In still others, no data are available. Nevertheless, no differences in diazinon use patterns are readily apparent among the various Bay Area urban watersheds. Therefore, the evidence suggests that diazinon in urban creeks is a widespread problem. The widespread pesticide-related toxicity observed in cities outside the Bay Area reinforces this conclusion (Bailey et al. 2000). For this reason, urban creeks for which little information is available are believed to be as likely to be impaired as those for which more information is available. Diazinon is therefore considered to potentially impair the habitat-related beneficial uses of all Bay Area urban creeks, including cold and warm freshwater habitat, fish migration and spawning, and preservation of rare and endangered species.

The 35 creeks specifically named on the 303(d) List include those that (1) drain to San Francisco Bay, (2) have been designated in the Basin Plan as having beneficial uses related to aquatic life, and (3) are within the jurisdiction of the Bay Area Stormwater Management Agencies Association (San Francisco Bay RWQCB 1998). Creeks within the Bay Area Stormwater Management Agencies Association's jurisdiction drain primarily urban and suburban areas. Many urban creeks are not specifically identified in the Basin Plan, but as discussed above, diazinon also likely impairs their habitat-related beneficial uses whether or not they are formally included on the list of impaired water bodies. Because diazinon management strategies will be most effective if implemented on a regional basis (as opposed to creek-by-creek), this TMDL process applies to all urban creeks. Urban creeks not formally recognized as impaired will benefit from the management efforts implemented through this TMDL process.

UNCERTAINTIES

Uncertainty is inherent to the TMDL process. The TMDL process does not seek to eliminate uncertainty; it seeks to gather sufficient information to justify actions resulting in the attainment of water quality standards. While available information supports concluding that Bay Area urban creeks are impaired and a TMDL is warranted, issues exist that are not fully understood. Some sources of uncertainty concerning pesticide-related toxicity include (1) the limitations of the tests used to assess aquatic toxicity and (2) the limitations that result from focusing the assessment on only the surface water column.

The Basin Plan requires that all waters be maintained free of toxic substances; however, U.S. EPA's "Whole Effluent Toxicity" test for freshwater measures a limited number of toxic effects. For example, the *Ceriodaphnia dubia* test measures only mortality and reproduction. The "Whole Effluent Toxicity" test does not evaluate other possible sublethal endpoints for *Ceriodaphnia dubia*, nor does it address the full range of possible effects for other species. For example, recent research has found that diazinon concentrations as low as 100 ng/l can inhibit the ability of some fish (e.g., salmon) to smell; therefore, diazinon exposure could be detrimental to fish that rely on their sense of smell to avoid predation or to perform other critical behavioral functions (Scholz et al. 2000, Moore and Waring 1996). These types of effects could be important to some organisms in Bay Area urban creeks.

The effects of diazinon and other pesticides on organisms that live in urban creek sediment have also not been studied in detail. The amount of diazinon in creek sediment can be substantial. In 1995, diazinon concentrations in the top 0.2 centimeters of muddy bank sediment from Castro Valley Creek and San Leandro Creek ranged from 4,100 to 33,100 nanograms per kilogram (ng/kg, parts per trillion). Diazinon concentrations in fine sediment collected from the top 8 centimeters of these streambeds ranged from 2,800 to 55,300 ng/kg (ACURCWP 1996). These concentrations are 10 to 100 times greater than the concentrations observed in the water column of Bay Area urban creeks. The availability of pesticides, including diazinon, for uptake by bottom-dwelling organisms is unknown. Likewise, the potential for any related toxicity to harm these important components of the creek habitat is also unknown. Furthermore, the tendency of pesticides such as diazinon to persist in this sediment is not fully understood (ACCWP 1999a).

KEY POINTS

The evidence that pesticides impair water quality in Bay Area urban creeks is consistent and compelling:

1. Urban creek water has been found to be toxic to some aquatic organisms.

2. This toxicity has been linked directly to the presence of the pesticide diazinon.

3. Substantial quantities of diazinon and other pesticides are applied throughout the Bay Area.

4. Diazinon's physical properties allow it to move through the environment and enter urban creeks.

5. Diazinon levels in urban creeks often exceed California Department of Fish and Game water quality criteria.

For these reasons, urban creeks are not considered to be free of toxic pesticides (e.g., diazinon) in concentrations that are lethal to aquatic organisms at the lower levels of the food web, and the narrative toxicity objectives of the Basin Plan are not met. Therefore, pesticide-related toxicity, and diazinon-related toxicity in particular, impairs Bay Area urban creeks.

3. SOURCE ASSESSMENT

Diazinon has been identified as a cause of aquatic toxicity observed in San Francisco Bay Area urban creek water. This assessment summarizes what is known regarding the sources and conveyances of diazinon. It describes the magnitude of diazinon use in the Bay Area, available formulations, common application sites, and target pests, and discusses how this information pertains to pesticides more generally.

SOURCES OF PESTICIDES IN URBAN CREEKS

Figure 3.1 illustrates the conceivable pathways through which a generic pesticide applied in an urban area could reach surface water. In the specific case of diazinon discharges to Bay Area urban creeks, the predominant pathways are storm water runoff, dry weather discharges from storm drains, and possibly direct discharges (e.g., dumping) (CDPR 2001b). This conclusion follows from the elimination of the other possible pathways suggested in Figure 3.1, as discussed below.

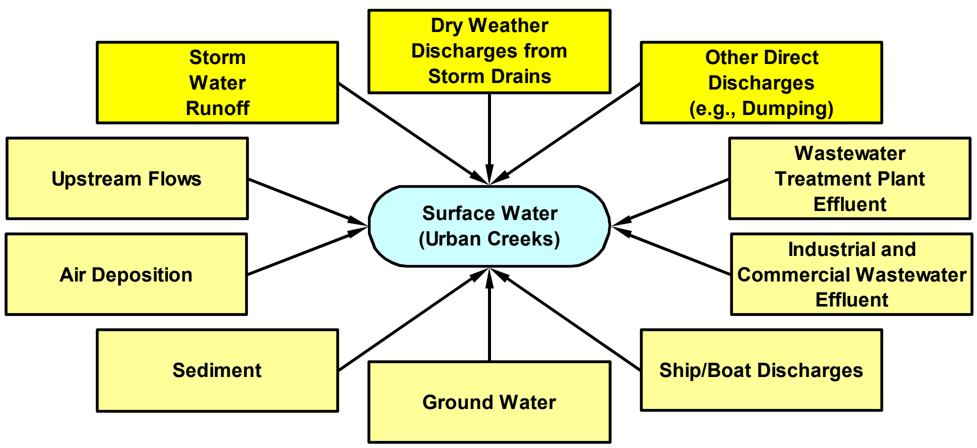

FIGURE 3.1
Conceivable Pathways for a Generic Pesticide to Reach Surface Water

In the Bay Area, wastewater treatment plants and industrial and commercial facilities do not typically discharge into urban creeks. Their discharges flow directly to San Francisco Bay or the Pacific Ocean. Shipping and boating do not typically involve diazinon use and do not occur in Bay Area urban creeks; therefore, they are not known sources. Watersheds upstream from Bay Area urban areas are primarily open space; consequently, upstream flows are not a major source of diazinon in Bay Area urban creeks. Air deposition could contribute diazinon to upstream flows, but air deposition is primarily a conveyance mechanism for diazinon from other sources (see Section 4, Linkage Analysis). Sediment is another type of conveyance. It carries diazinon from place to place when a diazinon-laden particle reaches a creek or forms within a creek. Groundwater is also not believed to be a significant source of diazinon in urban creeks because diazinon adheres strongly to particles and is seldom found beyond the top 0.5 inches of affected soil (ETN 1996). Diazinon has been detected in less than 2% of shallow groundwater samples from urban areas, with the highest level reported being 10 nanograms per liter (ng/l, parts per trillion) (U.S. EPA 2000f).

While direct discharges to surface water could occur, most diazinon discharges flow to storm drain systems. The relative size of the urban areas draining directly to creeks via overland flow is very small compared to the relative size of urban areas draining to storm drains. Diazinon discharges resulting from random illicit activity or accidental spills, therefore, are far more likely to flow into a storm drain system than directly into a creek. Regardless of this distinction, however, the pest management activities that result in direct diazinon discharges to urban creeks and discharges to storm drain systems are essentially the same. Therefore, this report does not address them separately.

For the reasons stated above, storm drain systems are believed to be the sources of essentially all the diazinon in urban creeks. Storm water runoff and dry weather discharges both flow through storm drains systems. For a particular creek, the storm drain systems that flow into that creek are the sources of diazinon to that creek.

Storm drain systems are regulated as point sources, and in large urban areas, including most of the Bay Area, storm drain systems are subject to National Pollutant Discharge Elimination System (NPDES) permits. Of the Bay Area counties in which urban creeks are considered impaired, Alameda County, Contra Costa County, San Mateo County, and Santa Clara County have countywide NPDES permits for their storm drain systems. In Solano County, the Cities of Vallejo, Fairfield, and Suisun have NPDES permits for their storm drain systems.

REPORTED AND UNREPORTED DIAZINON APPLICATIONS

Diazinon does not naturally occur in the environment; it is manufactured. Diazinon was originally registered for use with the U.S. Environmental Protection Agency in 1956. Syngenta manufactures diazinon and is currently the lead registrant. Other manufacturers and formulators (companies that formulate commercial products with the diazinon manufactured by others) include Mahketshim-Agan, Drexel, Prentis, Gowan, and Aventis (U.S. EPA 2000a). As shown in Figure 3.2, these companies sell diazinon products to distributors and retailers. Retailers then sell them to the agricultural users, structural pest control operators, professional landscape maintenance gardeners, and private citizens who apply them. In the Bay Area, the diazinon in runoff flowing to urban creeks through storm drain systems results from these diazinon applications.

Diazinon is the active ingredient in many pesticide product formulations. Most of these formulations also contain so-called “inert” substances at various concentrations. This

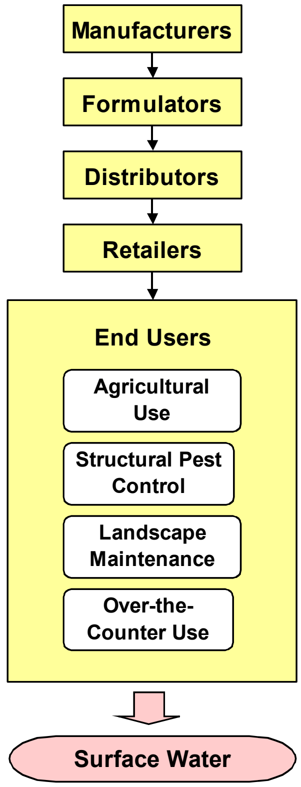

FIGURE 3.2
Parties Responsible for Pesticides in Urban Creeks

report uses the term "diazinon" to refer to the active ingredient only, not to the entire product. The many inert ingredients are not considered when quantities of diazinon are discussed below.

California requires all agricultural pesticide applications to be reported to local Agricultural Commissioners. The California Department of Pesticide Regulation, in turn, compiles these data. "Agriculture" is defined to include applications on parklands, golf courses, rights of way, rangelands, pastures, and cemeteries (i.e., anything but residential, industrial, and institutional sites). Commercial pest control operators apply diazinon primarily for structural pest control and landscape maintenance, and they must report their pesticide applications. In contrast, private citizens are not required to report applications of products sold over-the-counter at private homes and gardens.

The City of Palo Alto has estimated that, in urban areas, unreported diazinon applications account for up to 60% of all diazinon applications, and reported diazinon applications may represent as little as 40% (Palo Alto 1996). On the basis of estimated sales in Castro Valley and reported applications there, Alameda County has estimated that reported and unreported applications each account for about 50% of all diazinon applications (Alameda County 1997).

As noted in Table 3.1, about 85,000 pounds of diazinon were reportedly applied in the nine Bay Area counties each year from 1995 to 2000 (CDPR 2001a; CDPR 2000a; CDPR 2000b; CDPR 1999a; CDPR 1999b; CDPR 1996). When estimating diazinon applications within the San Francisco Bay Regional Water Quality Control Board's (Regional Board's) jurisdiction, the difference between the county boundaries used for pesticide reporting and the Regional Board boundaries (which are based on watershed drainage areas) introduces some uncertainty. Some of the nine Bay Area counties straddle Regional Board boundaries, so a relatively small portion of this reported diazinon was applied outside the San Francisco Bay Regional Water Quality Control Board's jurisdiction. However, areas outside the Regional Board's jurisdiction tend to be more rural, and areas within the Regional Board's jurisdiction tend to be more urban. Landscape maintenance and structural pest control are more closely associated with urban areas than most agricultural activities. Therefore, when using county data to estimate reported diazinon applications within the Regional Board's jurisdiction, the pesticide use reported for structural pest control and landscape maintenance may be only slightly overstated, and the pesticide use reported for agriculture may be substantially overstated.

TABLE 3.1
Reported Diazinon Applications in the Bay Area, 1995-2000

	Reported Applications (pounds)					
Purpose	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Structural Pest Control	49,119	50,032	45,700	49,541	50,552	34,071
Agriculture	28,113	25,214	26,061	22,034	23,271	13,472
Landscape Maintenance	18,500	14,468	15,961	18,274	11,382	13,740
Other*	128	80	777	555	115	1,187
Total	*95,859*	*89,795*	*88,499*	*90,403*	*85,321*	*62,469*

* Other uses of diazinon included public health pest control, research commodities, rights of way, and uncultivated areas.
Source: CDPR 2001a; CDPR 2000a; CDPR 2000b; CDPR 1999a; CDPR 1999b; CDPR 1996.

As illustrated in Figure 3.3, diazinon applications vary from year to year. These variations may reflect differences in weather, specific pest problems, or recent general trends. Table 3.2 shows average reported diazinon applications by county for the period from 1995 through 2000. During this period, more diazinon applications were reported in Santa Clara County than in any other Bay Area county. Contra Costa County ranked second. About 54% of the total diazinon reportedly applied was associated with structural pest control, about 27% was associated with agriculture, about 18% was associated with landscape maintenance, and about 1% was for other types of applications (CDPR 2001a; CDPR 2000a; CDPR 2000b; CDPR 1999a; CDPR 1999b; CDPR 1996).

Given that from 1995 to 2000 an average of 85,391 pounds of diazinon applications were reported each year for the nine Bay Area counties, and assuming that reported and

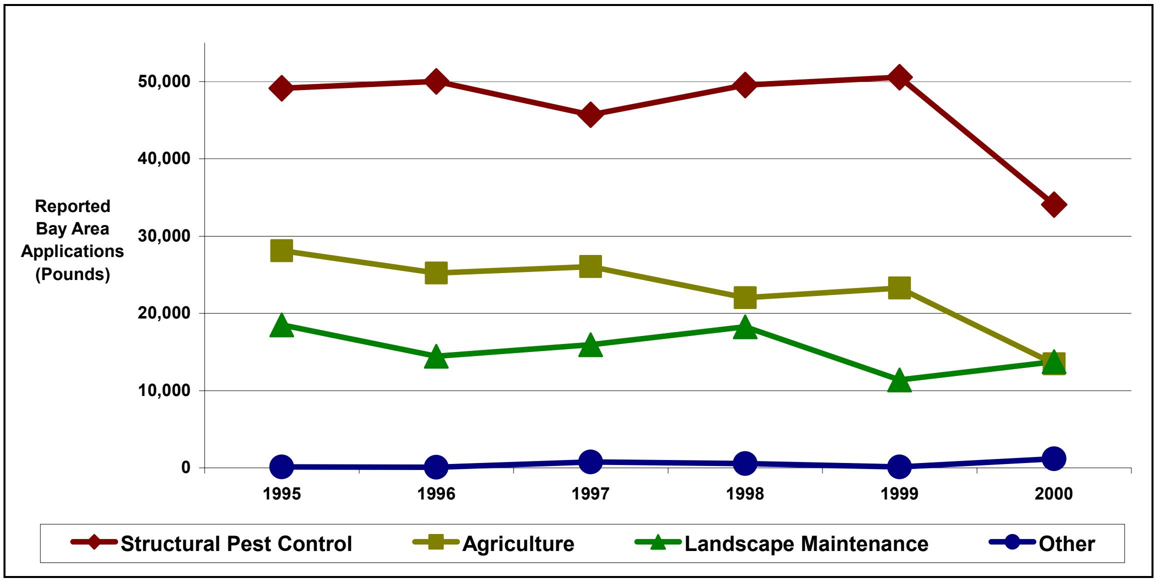

FIGURE 3.3
Reported Diazinon Applications in the Bay Area, 1995-2000

TABLE 3.2
Average Reported Diazinon Applications by Bay Area County, 1995-2000

County	Average Reported Applications (pounds)			
	Structural Pest Control	Agriculture	Landscape Maintenance	Other*
Alameda County	7,077	18	1,840	3
Contra Costa County	10,359	5,185	3,660	14
Marin County	2,485	10	579	0
Napa County	383	90	28	1
San Francisco County	597	0	19	0
San Mateo County	6,053	1,028	1,187	359
Santa Clara County	15,596	7,531	6,543	65
Solano County	2,237	6,022	107	30
Sonoma County	1,714	3,142	1,425	1
Subtotal	*46,502*	*23,028*	*15,387*	*473*
Percent of Total	*54%*	*27%*	*18%*	*1%*

* Other uses of diazinon included public health pest control, research commodities, rights of way, and uncultivated areas.
Source: CDPR 2001a; CDPR 2000a; CDPR 2000b; CDPR 1999a; CDPR 1999b; CDPR 1996.

unreported applications were each about 50% of the total (Alameda County 1997), then about 85,400 pounds of diazinon applications were probably not reported. The total amount of diazinon applied in the Bay Area, therefore, may have been about 170,800 pounds or about 85 tons per year. On the basis of the data in Table 3.2, these 85 tons were probably distributed roughly as illustrated in Figure 3.4.

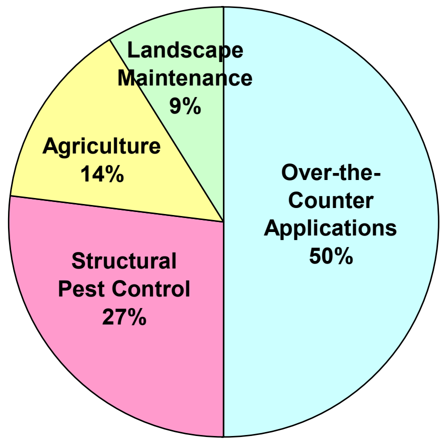

FIGURE 3.4
Distribution of Diazinon Applications in the Bay Area

Alameda County has estimated the annual amount of diazinon applied outdoors to be about 0.02 pounds per person (Alameda County 1997). The population of the Bay Area is about 6,948,000 (a relatively small portion of which reside outside the jurisdiction of the Regional Board) (ABAG 2001). Therefore, Bay Area residents could apply about 140,000 pounds or about 70 tons of diazinon outdoors each year. This estimate agrees reasonably well with the above total indoor and outdoor estimate of 85 tons, particularly if most diazinon is assumed to be applied outdoors.

DISTRIBUTION OF DIAZINON WITHIN THE WATERSHED

The distribution of diazinon in urban creeks provides clues about how it is applied in urban areas and the paths it takes to reach surface water. To better understand the distribution of diazinon in urban creeks, the Alameda Countywide Clean Water Program investigated the Castro Valley Creek watershed, which is believed to be typical of many Bay Area urban watersheds. Land uses in that watershed are about 50% low-density residential development, 35% open space, and 15% commercial development (including multifamily residential areas). On the basis of numerous concentration measurements and corresponding flow data, Alameda County estimated the total amount of diazinon discharged to Castro Valley Creek to be about 1.3 pounds during the 1995-1996 rainy season. As Figure 3.5 illustrates, this load represents a very small fraction (about 0.25%) of the diazinon Alameda County estimated was applied outdoors in the watershed (ACCWP and Alameda County 1997). Assuming that about 0.25% of the 85 tons of

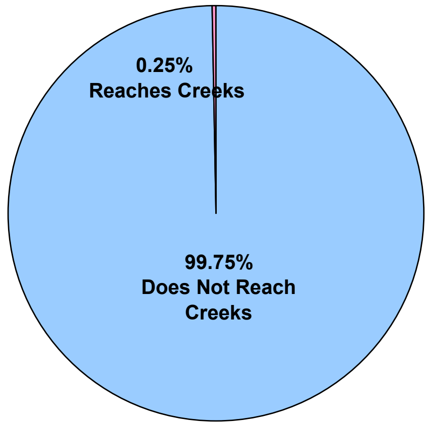

FIGURE 3.5
Relationship Between Diazinon Applications
and Diazinon Loads in Urban Creeks

diazinon applied throughout the entire Bay Area finds its way to surface water, the annual diazinon load to all Bay Area creeks is roughly 400 pounds.

Analysis of storm water samples collected from the Castro Valley Creek watershed indicated that diazinon applied on surfaces during dry weather appeared to accumulate before washing into the creek during storms. The mass of diazinon discharged to the creek increased with increased flow, although diazinon concentrations decreased, presumably through dilution. Diazinon concentrations were higher in residential and commercial areas compared to those with more open space. Higher diazinon levels were not clearly associated with any particular neighborhoods, however, and diazinon samples from adjacent gutters draining separate residences sometimes exhibited very different concentrations. Alameda County concluded that diazinon comes from multiple, sporadic sources. Individual sources may be very localized, and downstream diazinon levels apparently reflect an average of upstream pulses. At any one time, about 2 to 4% of the properties in residential areas could be contributing diazinon to urban runoff. Some consistent diazinon discharges may also exist in the Castro Valley Creek watershed because some relatively high diazinon concentrations occurred at certain locations during more than one sampling event (ACCWP and Alameda County 1997).

The Alameda Countywide Clean Water Program also studied the San Leandro Creek watershed and came to similar conclusions. Street gutter samples collected from residential areas during a storm exhibited low diazinon concentrations in many areas and high levels in a few areas. Creek samples were more uniform and reflected the average of many different storm water discharges (ACCWP 1999b). The data suggest that diazinon applications at discrete, variable, and independent locations are responsible for the diazinon observed in surface water.

Although most of the diazinon applied in the Bay Area adheres to organic surfaces, degrades in the environment, and is not found in surface water, the relatively small fraction that does reach surface water is responsible for the aquatic toxicity observed in urban creeks. This estimated diazinon load (about 0.25% of the amount applied outdoors) is consistent with runoff that has been observed from routine applications in other areas (Capel et al. 2001). It does not necessarily suggest runoff from isolated and sporadic illicit or accidental activities, although these could also occasionally contribute to the overall load.

The Alameda Countywide Clean Water Program conducted tests to determine if applying diazinon outdoors in accordance with its label instructions could account for observed surface water concentrations. A liquid diazinon concentrate was diluted and applied at a home in accordance with label instructions (except that the amount of diazinon applied was considerably less than the recommended application rate for ants). During subsequent rainfall, runoff concentrations reached as high as 1,200,000 ng/l several days after the application. The water quality criterion developed by the California Department of Fish and Game for chronic exposure is 50 ng/l, and the criterion for acute exposure is 80 ng/l. The highest runoff concentrations occurred when rain closely followed the application, and high diazinon levels persisted for up to seven weeks. The study concluded that applying diazinon in accordance with label instructions could not be ruled out as a source of diazinon in storm water (ACCWP and Alameda County 1997).

FORMULATIONS, APPLICATION SITES, AND TARGET PESTS

Formulations

The roughly 400 pounds of diazinon discharged to Bay Area surface water each year is from various products and formulations. Table 3.3 provides examples of several existing diazinon formulations. Many other pesticides are formulated similarly. Of the formulations listed in Table 3.3, impregnated materials and pressurized liquids, sprays, and foggers are intended primarily for indoor use (although aerosol products may be applied outdoors). The other types of formulations are all applied outdoors.

The relative effect of formulation on water quality depends on (1) how much product is applied and (2) how much of the pesticide in the formulation typically runs off site. Little information is available regarding how diazinon runoff varies with formulation. On the basis of the limited available data, however, wettable powders appear to offer the greatest

potential for concern. Wettable powders are widely applied to impervious surfaces by pest control operators, and when exposed to water (e.g., rain), they are easily re-suspended. Emulsifiable concentrates, granules, and flakes are also common formulations. Studies suggest that emulsifiable concentrates may be more prone to run off than granules and flakes, but not more prone to runoff than wettable powders (CDPR 2001b).

TABLE 3.3
Examples of Diazinon Product Formulations

Formulation	Number of Products*	Product Examples
Granules and Flakes	80	Turf products
Emulsifiable Concentrates	45	Insect spray concentrates
Impregnated Materials	35	Pet flea collars
Pressurized Liquids, Sprays, and Foggers	21	Ant and roach sprays and "bombs"
Aqueous (Liquid) Concentrates	18	Concentrates for mixing insect sprays
Solutions and Liquids (Ready to Use)	18	Ant, roach, and spider sprays for home use
Wettable Powders	12	Professional applicator products
Dusts and Powders	8	Insecticide dusts
Microencapsulated Materials	6	"Controlled release" liquid sprays (concentrates and ready-to-use)

* The number of products includes those registered in California as of September 2000. It does not indicate the relative amount of diazinon applied with each formulation.
Source: CDPR 2001b.

Application Sites

Most over-the-counter diazinon products are applied outdoors. Indoor diazinon applications may result in wastewater discharges, but because Bay Area wastewater treatment plants do not discharge to urban creeks, indoor applications do not result in discharges to urban creeks. A limited survey of retail outlets in Alameda County determined that about 70% of the pesticide products sold there were concentrates, about 30% were granules, less than 1% were dusts, and less than 1% were diluted (i.e., ready-to-use) products. These products are commonly applied outdoors. Alameda County also interviewed three structural pest control operators. About 90% of their work was for residential properties, and their diazinon applications were exclusively outdoors (Alameda County 1997).

Because diazinon levels in Castro Valley Creek had been studied, and because Castro Valley's mostly low-density residential development is representative of much of Alameda County, Alameda County conducted a telephone survey of Castro Valley residents to learn more about their pest management practices. The results indicate that about 51% of Castro Valley residents apply some type of pesticide outdoors. Of these, about 35% apply the pesticide themselves, and about 14% hire a professional. As shown in Figure 3.6, the pesticides are applied at building foundations, in gardens, along patios and walkways, on trees and shrubs, and on lawns.

As with pesticide formulations, the relative effect of application site on water quality depends on (1) how much product is applied at the site and (2) how much of the pesticide at the site typically runs off. On the basis of available data, applications to impervious surfaces appear to offer the greatest potential for concern (CDPR 2001b). As shown in Figure 3.4, structural pest control applications are among the most common uses of diazinon, and structural pest control operators predominantly apply diazinon to impervious surfaces. As suggested by Figure 3.6, many homeowners also apply over-the-counter pesticides to impervious surfaces. Diazinon applied to impervious surfaces degrades less rapidly than diazinon applied to plants or soil because it is exposed to less microbial activity (U.S. EPA 2000f). Moreover, impervious surfaces do not absorb water, so more runoff occurs and more diazinon reaches urban creeks.

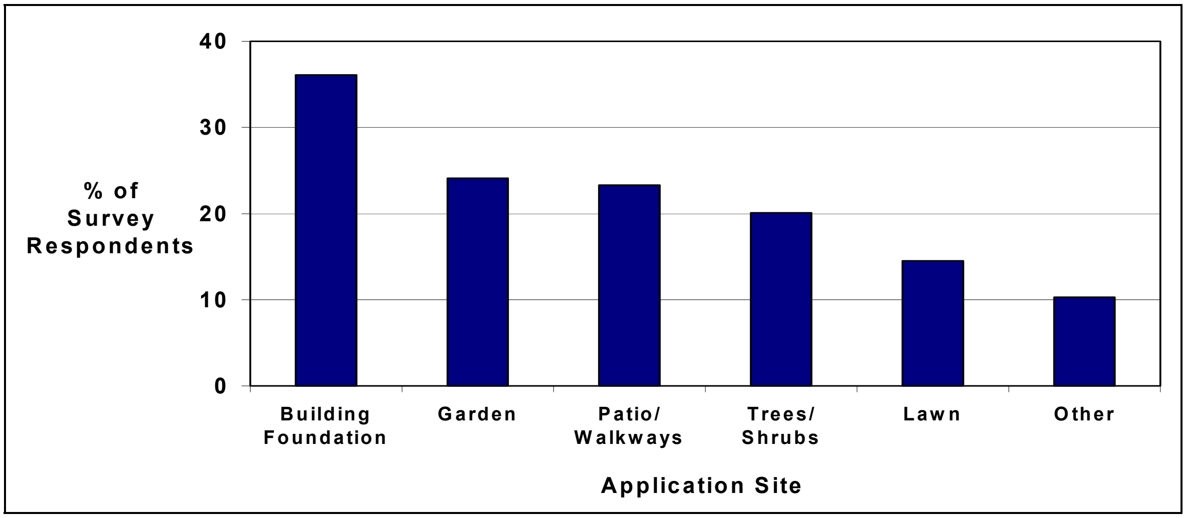

FIGURE 3.6
Pesticide Application Sites
Reported by Castro Valley Residents

In addition to impervious surfaces, applications to plants and soils also pose substantial concern for water quality. Figure 3.6 demonstrates that many homeowners apply pesticides to landscaping, including plants and soil. Figure 3.4 indicates that these over-the-counter uses account for a substantial portion of diazinon applications. Professional landscape maintenance gardeners also apply diazinon to plants and soil. Although diazinon runoff from landscaped areas may not be as great as diazinon runoff from impervious surfaces, as much as 1% of diazinon applied to turf has been found to run off (Evans 1998). Therefore, diazinon applications to plants and soil pose substantial water quality concerns.

Target Pests

Like any pesticide, diazinon is used to manage pest problems. Pest management literature and outreach programs are often organized by target pest (e.g., ants, fleas, grubs, and other pests), not pesticide. The target pest determines the available product formulations, appropriate application sites, and required application techniques. In turn, these factors determine the potential for surface water discharges. As shown in Figure 3.7, the most common pest problems reported during the Castro Valley survey were ants, followed by spiders, fleas, and aphids. Of the 69% of survey respondents who could name a pesticide applied at their homes, more named diazinon (32%) than any other pesticide (Alameda County 1997).

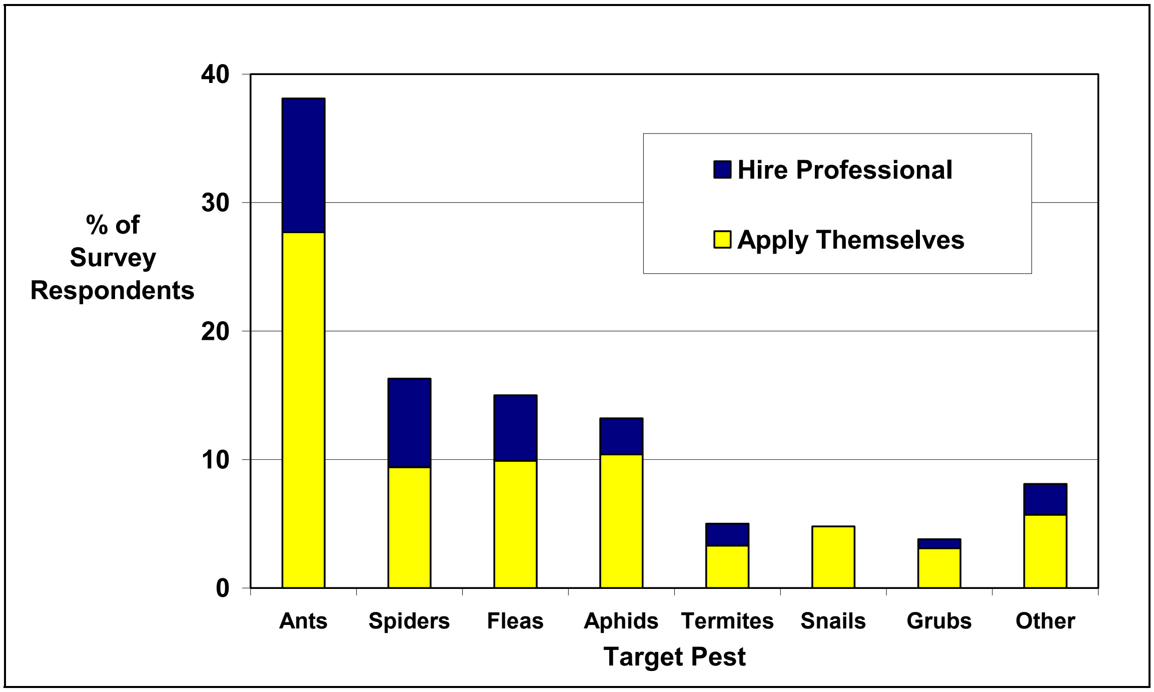

FIGURE 3.7
Pest Problems Reported by Castro Valley Residents

Landscaping-related pesticide applications correlate with seasonal pest management challenges. They peak in July and are lowest in January. Structural pest control applications are similarly low in January, although the seasonal fluctuation is considerably less (Alameda County 1997). Retail diazinon sales begin in spring and pick up through summer; however, ant-related applications pick up during the rainy season (i.e., winter) when ants are more likely to come indoors (Palo Alto 1996). As seasonal factors affect pest problems, they also affect pesticide use and runoff.

KEY POINTS

This source assessment can be summarized as follows:

- The primary source of diazinon in urban creeks is urban runoff discharged through storm drain systems. Urban runoff includes storm water runoff and non-storm discharges, such as irrigation runoff.

- Pesticides are discharged with urban runoff as a result of being manufactured, formulated into products, and sold through distributors and retailers to businesses and individuals. These businesses and individuals apply pesticides for agricultural, structural pest control, landscape maintenance, and other pest management purposes.

- Inappropriate pesticide handling practices may account for some of the diazinon detected in urban runoff, but legal applications in accordance with label instructions may be responsible for much of this diazinon.

- Product formulations affect the potential for pesticide runoff. Wettable powders appear to pose the greatest risks to water quality. Emulsifiable concentrates also pose risks. Granules and flakes pose lesser risks.

- Impervious surfaces are among the application sites that pose the greatest risks to water quality. Applications to plants and soil also pose substantial risks.

- The most commonly reported insect pests in the Bay Area are ants, but pesticides are also applied to manage spiders, fleas, aphids, and many other insects.

Over-the-counter pesticide uses are believed to be among the greatest contributors to the pesticides (e.g., diazinon) in urban runoff. Over-the-counter pesticide products are applied to impervious surface, plants, soils, and other surfaces. The most common pest problem reported by residents is ants; therefore, ant control practices, in particular, may be among the greatest contributors to pesticide discharges.

Pesticide applications by structural pest control operators also contribute to pesticides, particularly diazinon, in urban runoff. Structural pest control operators apply substantial quantities of wettable powders and emulsifiable concentrates to impervious surfaces (e.g., building perimeters). Ant control is a leading market for structural pest control professionals; therefore, ant control practices may be among the greatest contributors to diazinon discharges.

Pesticide applications by professional landscape maintenance gardeners are smaller contributors to pesticide runoff. Gardeners apply diazinon to plants and soil to address a number of pest problems. Agricultural applications contribute less to pesticide runoff; however, applications that are considered agricultural do occur in urban areas, including applications on parklands, rights of way, and cemeteries.

4. NUMERIC TARGETS

Bay Area urban creeks receive sufficient diazinon loads to result in diazinon concentrations that exceed water quality standards. As shown in Figure 4.1, the effects of diazinon sources on urban creeks can be measured in terms of diazinon concentrations and toxicity. Measures of toxicity incorporate the combined effects of chemical mixtures (e.g., mixtures of pesticides with similar toxic effects) and other environmental stressors. To protect aquatic life in Bay Area urban creeks, diazinon concentrations and aquatic toxicity must be controlled.

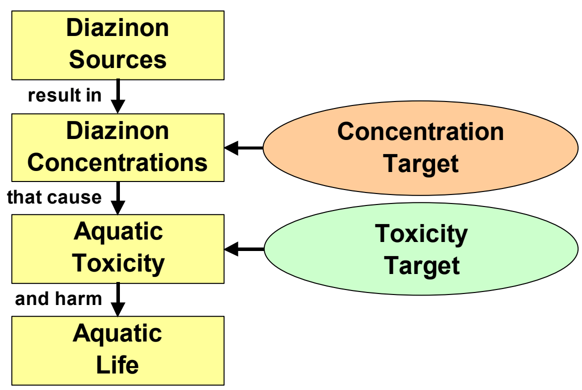

FIGURE 4.1
Target Indicators to Control
Diazinon Impairment of Aquatic Life Beneficial Uses

The Total Maximum Daily Load (TMDL) process calls for the development of numeric targets that, if achieved, ensure attainment of water quality standards (i.e, attainment of water quality objectives necessary to protect beneficial uses and prevent degradation of existing water quality) (U.S. EPA 2000d). The *Water Quality Control Plan, San Francisco Bay Basin (Region 2)* (Basin Plan) does not provide a numeric water quality objective for diazinon, but it contains a narrative water quality objective for toxicity (San Francisco Bay RWQCB 1995):

> *All waters shall be maintained free of toxic substances in concentrations that are lethal to or that produce other detrimental responses in aquatic organisms….*

Numeric targets are needed to translate this narrative objective quantitatively. Numeric targets can be expressed in terms of mass, toxicity, or any other appropriate measure. They do not necessarily have to be adopted as new numeric water quality objectives, although they can become water quality objectives by amending the Basin Plan. Numeric targets appropriate for diazinon concentrations and pesticide-related toxicity in urban creeks are identified below and compared to existing conditions.

CONCENTRATION TARGETS

Several methods have been considered for the development of diazinon concentration targets (Central Valley RWQCB 2001a; Central Valley RWQCB 2001b). Table 4.1 reviews the primary options and lists some of their advantages and disadvantages. A review of these alternatives suggests that the best approach is to develop concentration targets using U.S. Environmental Protection Agency (U.S. EPA) guidelines for deriving water quality criteria (U.S. EPA 1985). This approach protects known sensitive organisms and accounts for the effects of acute (short-term) and chronic (long-term) exposure.

Application of U.S. EPA's published guidelines for the development of water quality criteria results in two concentration-based criteria to protect aquatic life (U.S. EPA 1985). One criterion relates to the effects of acute exposure, and one relates to the effects of chronic exposure. The acute criterion is a one-hour average not to be exceeded more than once every three years. The chronic criterion is a four-day average not to be exceeded more than once every three years. These water quality criteria are intended to protect most aquatic organisms most of the time.

U.S. EPA's guidance specifies minimum data quality requirements for the toxicity studies used to derive the criteria (U.S. EPA 1985). The process requires data from at least eight different families of organisms, including specific fish species, other vertebrates, and invertebrates. The acute criterion is derived LC_{50} data (chemical concentrations lethal to 50% of test organism exposed for a given duration) collected for several species within different genera (taxonomic classification comprised of similar species). A theoretical concentration is calculated that is lower than the average LC_{50} for the genus whose average LC_{50} is lower than 95% of the average LC_{50} values for the tested genera. Because a substantial number of organisms exposed to this concentration could experience up to 50% mortality, this concentration is divided by two to estimate a concentration likely to have little or no effect. The result is the acute criterion. The chronic criterion is derived from similar data using acute-chronic ratios (ratios observed between concentrations known to cause acute effects, such as mortality, and concentrations known to result in chronic effects, such as impaired growth or reproduction).

U.S. EPA and the California Department of Fish and Game have independently developed water quality criteria using the U.S. EPA method. Each has made distinct assumptions that have resulted in somewhat different criteria. U.S. EPA concluded that the acute and chronic criteria should both be 100 nanograms per liter (ng/l, parts per trillion) (U.S. EPA 2000e). The California Department of Fish and Game concluded that the acute criterion should be 80 ng/l and the chronic criterion should be 50 ng/l (CDFG 2000). The California Department of Fish and Game criteria are lower than U.S. EPA's criteria because U.S. EPA considered an additional acute toxicity study and did not rely on a particular chronic toxicity study (CDFG 2001). Although both sets of criteria are reasonable, the California Department of Fish and Game's criteria are

TABLE 4.1
Methods for Deriving Numeric Concentration Targets for Diazinon

Method	Approach	Possible Target (ng/l)	Advantages and Disadvantages
Water Quality Criteria	Derive concentration intended to protect essentially all organisms by using toxicity data for sensitive species	50 - 100	• Relies on U.S. EPA method • Considers only data that meet minimum acceptability requirements • Ensures that almost all organisms experience almost no mortality (a reasonable facsimile of the Basin Plan toxicity objective) • Protects known sensitive organisms • Accounts for effects of acute and chronic exposure
Single-Species Toxicity Tests	Determine concentration that avoids toxicity to one sensitive indicator organism (e.g., *Ceriodaphnia dubia*)	100 - 500	• Directly relates to standard toxicity test upon which impairment is based • May not protect all organisms • May not adequately address effects of chronic exposure
Probabilistic Ecological Risk Assessment	Derive concentration protective of most species most of the time using toxicity data for a number of species and surface water quality monitoring data	200 – 4,000	• Requires an extensive database • Depends on the quality of available data (e.g., time and location of data collection and number of samples) • Does not typically account for effects of chronic exposure • Assumes some organisms may experience up to 50% mortality without damaging an ecosystem (inconsistent with the Basin Plan toxicity objective)
Microcosm and Mesocosm Studies	Study toxicological effects under quasi-natural conditions by using small and medium-scale experimental ecosystems	2,000 – 9,000	• Accounts for indirect ecological effects (e.g., effect on growth due to reduced food supply) • May inadequately mimic environmental conditions • May not protect all organisms, including those studied (available studies provide “lowest observed adverse effects concentration” but not “no observed adverse effects level”—see Figure 4.2)

ng/l, nanograms per liter
Source: Central Valley RWQCB 2001a; Central Valley RWQCB 2001b.

proposed as numeric targets for diazinon concentrations in urban creeks because they are lower and, therefore, more protective.

Substantial reductions in diazinon concentrations are needed to achieve the proposed targets in Bay Area urban creeks. Diazinon is often detected in Bay Area urban creeks at concentrations that exceed the targets of 50 ng/l and 80 ng/l. For example, following 1994 and 1995 winter storms, diazinon concentrations in creeks throughout the Bay Area ranged from 38 to 590 ng/l (SWRCB et al. 1997). Mean diazinon concentrations in Castro Valley Creek during the 1995-1996 rainy season ranged from 180 to 820 ng/l following storms. In some cases, values over 150 ng/l persisted for up to one week (ACCWP and Alameda County 1997). During the 1995 and 1996 dry seasons, diazinon was detected in Castro Valley Creek at concentrations of up to 340 ng/l. In Crandall Creek, concentrations reached 442 ng/l. At three inlets to Tule Pond in Fremont, concentrations peaked at 3,000 ng/l (SWRCB et al. 1997).

TOXICITY TARGETS

The diazinon concentration targets are intended to protect beneficial uses from diazinon in surface water. However, they do not explicitly address potential interactions between diazinon and other chemicals or environmental stressors that may contribute to aquatic toxicity. For example, the diazinon concentration targets do not account for potential additive or synergistic (more than additive) effects of multiple pesticides or other chemicals in surface water. Diazinon is one of several pesticides used in the Bay Area that share a similar mechanism of toxicity (disruption of normal nerve function). The combined effects of diazinon and chlorpyrifos (both of which are organophosphorus pesticides) on *Ceriodaphnia dubia* are additive (Bailey et al. 1997). These pesticides coexist in Bay Area surface water. Synergistic effects have also been demonstrated in specific pesticide combinations (Pape-Lindstrom and Lydy 1997; Denton 2001).

The toxicity objective contained in the Basin Plan is intended to address mixtures of pollutants (San Francisco Bay RWQCB 1995):

> *The narrative water quality objective for toxicity…protects beneficial uses against mixtures of pollutants typically found in aquatic systems. This approach is used because numerical objectives for individual pollutants do not take mixtures into account and because numerical objectives exist for only a small fraction of potential pollutants of concern.*

As discussed further in Section 8, Implementation Strategy, recent U.S. EPA action may increase the potential for mixtures of pollutants to contribute to aquatic toxicity in urban creeks. U.S. EPA is phasing out most urban uses of diazinon by the end of 2004 (U.S. EPA 2000c). This action will likely decrease diazinon concentrations in urban creeks. As a result of removing this popular pesticide from the urban marketplace, however, other new and existing pesticides will likely replace diazinon. These pesticides may not currently contribute significantly to aquatic toxicity in urban creeks, but as their use increases, their concentrations in surface water—and their toxic effects—will likely increase as well.

The TMDL process requires the development of numeric targets for use in translating narrative water quality objectives. Because the proposed diazinon concentration targets do not address the market shift to pesticides other than diazinon, and because they do not account for pollutant mixtures in urban creeks, they may be insufficient to protect the beneficial uses of Bay Area urban creeks from pesticide-related aquatic toxicity. A toxicity target would more closely relate to the Basin Plan's narrative objective for toxicity and could complement the diazinon concentration targets. The selection of multiple targets is consistent with National Research Council recommendations that biological criteria be used in conjunction with chemical and physical criteria to measure whether beneficial uses are achieved (NRC 2001). A toxicity target could also ensure that the environmental benefits of U.S. EPA's actions to phase out diazinon in urban areas are not offset by new sources of toxicity.

Toxicity Target Development

Although there are several ways to measure the health of an aquatic ecosystem (e.g., studying indicator organisms, species diversity, population density, or growth anomalies, or conducting standard toxicity tests), the Basin Plan specifically refers to toxicity test methods developed as part of the Effluent Toxicity Characterization Program (San Francisco Bay RWQCB 1991). U.S. EPA has promulgated similar Whole Effluent Toxicity test methods (U.S. EPA 1993; U.S. EPA 1994). The Basin Plan discusses these test methods in the context of point sources, such as wastewater treatment plants. This test method discussion constitutes the most direct guidance the Basin Plan offers regarding the measurement of toxicity and the interpretation of the narrative toxicity objective. The Basin Plan does not discuss in detail other options for evaluating toxicity.

The standard toxicity tests for freshwater discharges involve three species—the zooplankton *Ceriodaphnia dubia* (a "water flea"), the phytoplankton *Selenastrum capricornutum* (a green algae), and the fish *Pimephales promelas* (the fathead minnow). These test organisms are exposed to water samples and their responses are compared to those of control organisms exposed to control water. A sample is considered toxic if it results in an adverse response that differs significantly from the response of control organisms. Depending on the organism used, the tests evaluate survival, growth, reproduction, or cell division, as shown in Table 4.2. These biological effects include a selection of both lethal and sublethal effects. Although the range of biological effects evaluated by these tests is limited, the tests reliably predict ecological responses (U.S. EPA 1991; U.S. EPA 1999).

Rather than explicitly defining numeric objectives for toxicity, the Basin Plan allows for evaluations to be made on a case-by-case basis (San Francisco Bay RWQCB 1995). U.S. EPA Region 9 has published guidance for incorporating Whole Effluent Toxicity tests into NPDES permits (U.S. EPA 1996). This guidance relies on the concept of "toxic units" to derive permit limits. A toxic unit is a measure of toxicity that behaves like a

TABLE 4.2
Toxicity Test Protocols

Species	Common Name	Acute Exposure Duration	Chronic Exposure Duration	Life Function Evaluated
Pimephales promelas	fathead minnow	1, 2, or 4 days	7 days	survival growth
Ceriodaphnia dubia	water flea	1, 2, or 4 days	7-8 days	survival reproduction
Selenastrum capricornutum	green algae		4 days	cell division

Source: San Francisco Bay RWQCB 1991; U.S. EPA 1993.

concentration in that it varies proportionally with the toxicity of a sample. This report uses an approach similar to U.S. EPA's guidance, but it modifies U.S. EPA's approach to accommodate some practical considerations and to retain consistency with the Basin Plan.

For purposes of this report, toxic units are defined for acute toxicity tests in terms of the "no observed adverse effect concentration" (NOAEC). The NOAEC is the highest tested concentration of sample water that causes no observable adverse effect to exposed organisms, as illustrated in Figure 4.2. "No observable adverse effect" can be interpreted to mean no effect that is both statistically significant and more than 20% greater than observed in control samples (Pesticide Workgroup, undated). The NOAEC is expressed as the percentage of sample water in the test solution. For example, an undiluted sample has a concentration of 100%. If no adverse effect were observed during a test on an undiluted sample, then the NOAEC would be 100%. If a more toxic sample were to exhibit significant toxic effects at a concentration of 100% sample water, but not at 50% sample water, then the NOAEC would be 50%. The NOAEC can also be estimated as the sample water concentration that causes a 25% reduction in a biological effect (e.g., growth or reproduction). This inhibition concentration (IC_{25}) is obtained by interpolating from actual sample concentrations used to measure effects (U.S. EPA 1991).

Acute toxic units (TU_a) are defined as follows:

$$TU_a = 100 / NOAEC$$

Toxic units for chronic toxicity tests are defined in terms of the "no observed effect concentration" (NOEC), which is analogous to the NOAEC for acute effects. Chronic toxic units (TU_c) are defined as follows:

$$TU_c = 100 / NOEC$$

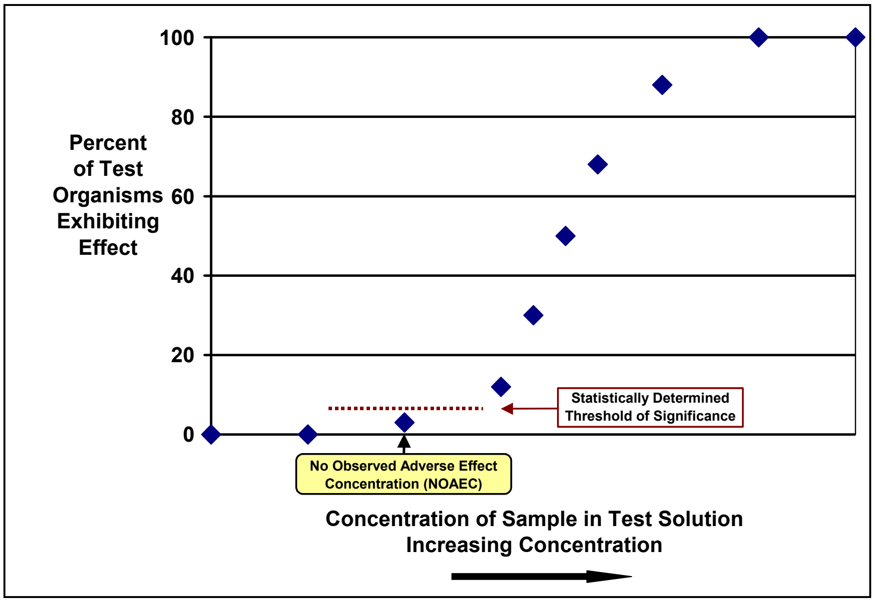

FIGURE 4.2
Conceptual Illustration of
"No Observed Adverse Effects Concentration"

The Basin Plan's narrative toxicity objective does not allow any acute or chronic toxicity in Bay Area creeks (San Francisco Bay RWQCB 1995):

> *There shall be no acute toxicity in ambient waters.... There shall be no chronic toxicity in ambient waters.... The health and life history characteristics of aquatic organisms in waters affected by controllable water quality factors shall not differ significantly from those for the same waters in areas unaffected by controllable water quality factors.*

According to the Basin Plan, no toxic effects should be observable in undiluted creek samples. This condition corresponds to NOAEC being at least 100% or no more than 1.0 TU_a, and NOEC being at least 100% or no more than 1.0 TU_c. Therefore, the proposed numeric toxicity targets are 1.0 TU_a and 1.0 TU_c.

Substantial toxicity reductions are needed to meet these proposed targets in Bay Area urban creeks. Toxicity has frequently been observed in Bay Area urban creek water. Of 125 samples collected from primarily Alameda County and Santa Clara County urban creeks from 1988 to 1995, 49% were lethal to 50% of *Ceriodaphnia dubia* test organisms within 96 hours (BASMAA 1996). In these cases, the creek water exceeded the proposed toxicity target of 1.0 TU_a.

Toxicity studies have reported that exposing *Ceriodaphnia dubia* for seven days to a water sample containing only diazinon resulted in a NOEC of about 220 ng/l. A four-day exposure resulted in a NOAEC of about 350 ng/l (CDFG 2000). Diazinon concentrations in Bay Area urban creeks often exceed these levels (SWRCB et al. 1997; ACCWP and Alameda County 1997). Because urban creeks contain other pesticides and environmental stressors, diazinon concentrations may need to be reduced below these levels to achieve the proposed toxicity targets.

Practical Considerations

The proposed numeric toxicity targets are not intended to be substantially different than the Basin Plan's narrative toxicity objective. They simply express the narrative objective numerically as required for TMDLs. Basing the toxicity targets on standard laboratory toxicity tests is not intended to limit the types of methods that can be used to evaluate toxicity.

As a practical matter, determining a NOAEC (acute tests) or NOEC (chronic tests) requires conducting toxicity tests at multiple concentrations. However, testing multiple concentrations may not always be necessary to determine whether a sample exceeds the proposed targets. An undiluted sample that does not exhibit significant adverse effects when compared to control samples would meet the proposed targets. Further testing would only be needed if significant toxicity were observed. Testing at multiple concentrations would allow the magnitude of the observed toxicity to be measured. Such tests would not be new; identification and characterization of toxicity in urban creeks remain important responsibilities of municipal storm water programs.

As another practical matter, not all toxic water samples necessarily contain pesticides. The selection of numeric toxicity targets for this TMDL is not intended to address the full range of possible toxic stressors. If the proposed toxicity targets were substantially and consistently exceeded, additional study (i.e., toxicity identification evaluation) could be warranted to determine the cause of the toxicity. If the cause were related to pesticides, management efforts associated with this TMDL could apply, but exceptions could also be considered if the substantial toxicity were found to be unrelated to pesticides. In this case, separate investigations could be warranted, including actions beyond the scope of this TMDL.

ANTIDEGRADATION

Numeric targets developed for TMDLs must be consistent with antidegradation policies. Section 131.12 of Title 40 of the Code of Federal Regulations contains the federal antidegradation policy. State Water Resources Control Board Resolution 68-16 contains California's antidegradation policy. These antidegradation policies are intended to protect beneficial uses and the water quality necessary to sustain them. When water quality is sufficient to sustain beneficial uses, it cannot be lowered unless doing so is consistent with the maximum benefit to the citizens of California. Even then, water quality must sustain existing beneficial uses.

The proposed numeric targets are designed to implement the Basin Plan's narrative water quality objectives for toxicity. They are essentially translations of the narrative objectives, which have already been established. To be consistent with the antidegradation policies, these targets, taken together, cannot be less stringent than the narrative objectives. The combination of the proposed numeric targets is at least as protective as the narrative objectives. Since at times diazinon concentrations and toxicity already exceed the narrative objectives, meeting the numeric targets would improve current water quality conditions. Therefore, the proposed targets are consistent with the antidegradation policies and the protection of water quality and beneficial uses.

KEY POINTS

The numeric targets proposed for diazinon in Bay Area urban creeks are:

> *The four-day average concentration of diazinon in freshwater shall not exceed 50 ng/l more than once every three years on the average.*
>
> *The one-hour average concentration of diazinon in freshwater shall not exceed 80 ng/l more than once every three years on the average.*

The proposed numeric targets for pesticide-related toxicity are:

> *The number of toxic units in freshwater, as determined through standard laboratory tests, shall not exceed 1.0 TU_a or 1.0 TU_c more than once every three years on the average.*

These targets apply to the water in freshwater creeks in urban areas throughout the Bay Area. Together, the proposed numeric targets complement each other to protect water quality. The diazinon concentration targets ensure that the current primary contributor to pesticide-related aquatic toxicity in Bay Area urban creeks will not be discharged at levels high enough to cause toxicity. The toxicity targets address potential interactions among multiple chemicals and environmental stressors, and ensure that the foreseeable phase-out of diazinon and resulting shift in pesticide use patterns will not replace one cause of toxicity with another. The targets are also consistent with state and federal antidegradation policies.

5. LINKAGE ANALYSIS

Numeric concentration and toxicity targets have been proposed to quantifiably evaluate attainment of the *Water Quality Control Plan, San Francisco Bay Basin (Region 2)*'s narrative toxicity objectives. Because these numeric targets were developed specifically to translate the narrative objectives, they are directly linked to the objectives. The purpose of this linkage analysis is to describe the links between the sources of diazinon and pesticide-related toxicity in urban creeks and the proposed numeric targets.

CONCEPTUAL MODEL

This report presents a conceptual model that represents the current understanding of the physical, chemical, and biological processes underlying pesticide behavior in the environment. The model frames a discussion of diazinon's transport mechanisms to urban creeks and its environmental fate and effects.

Figure 5.1 illustrates the general path that pesticides follow from application sites to urban creeks. The initial release occurs during structural pest control, landscape maintenance, and other outdoor applications to soils, plants, and paved areas (e.g., sidewalks, driveways, and patios). The pesticide is then transported in surface runoff to storm drains during rain or irrigation events. Storm water containing pesticides is discharged into urban creeks at storm drain outfalls. Although a relatively small fraction (about 0.25%) of the diazinon applied outdoors reaches urban creeks (ACCWP and Alameda County 1997), this small fraction is sufficient to exceed the proposed diazinon concentration and toxicity targets.

As pesticides move from application sites to creek habitats, several processes affect pesticide concentrations in urban creeks. For diazinon, the most important of these are degradation, evaporation and deposition, and sediment transport, as illustrated in Figure 5.2.

Degradation

Most diazinon applied in the Bay Area breaks down in the environment before it reaches urban creeks. As illustrated in Figure 5.3, one of diazinon's degradation products is diazoxon, which is believed to be largely responsible for the toxic effects associated with diazinon. Diazoxon degrades relatively quickly into less toxic chemicals, including oxypyrimidine (Larkin and Tjeerdema 2000).

Diazinon decomposes through photolysis, hydrolysis, and biological degradation. Photolysis is not typically an important degradation pathway for diazinon (U.S. EPA 2000f). Hydrolysis is rapid under acidic conditions (pH 5), where the diazinon half-life is about 2 weeks. However, under neutral and alkaline conditions, diazinon hydrolizes more slowly, with half-lives of about 20 weeks at pH 7 and about 11 weeks at pH 9 (U.S. EPA 2000f). Although hydrolysis may account for substantial diazinon

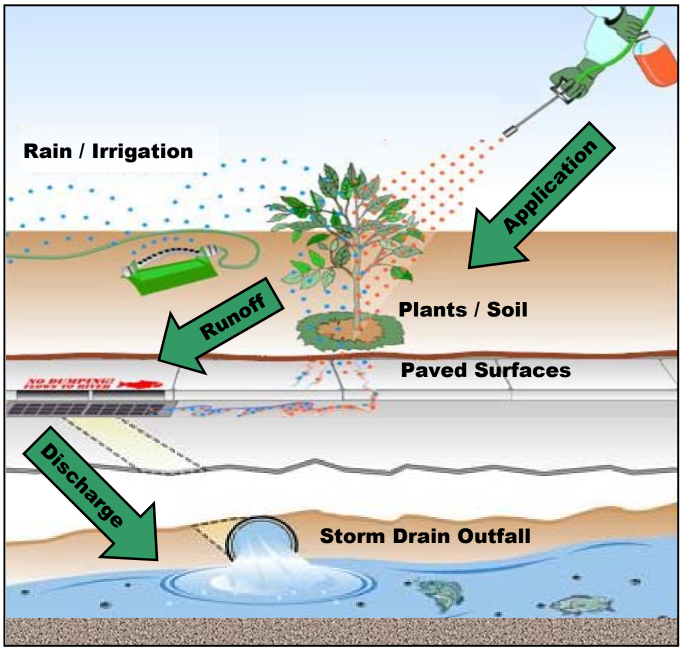

FIGURE 5.1*
Primary Path of Pesticide Discharges to Urban Creeks

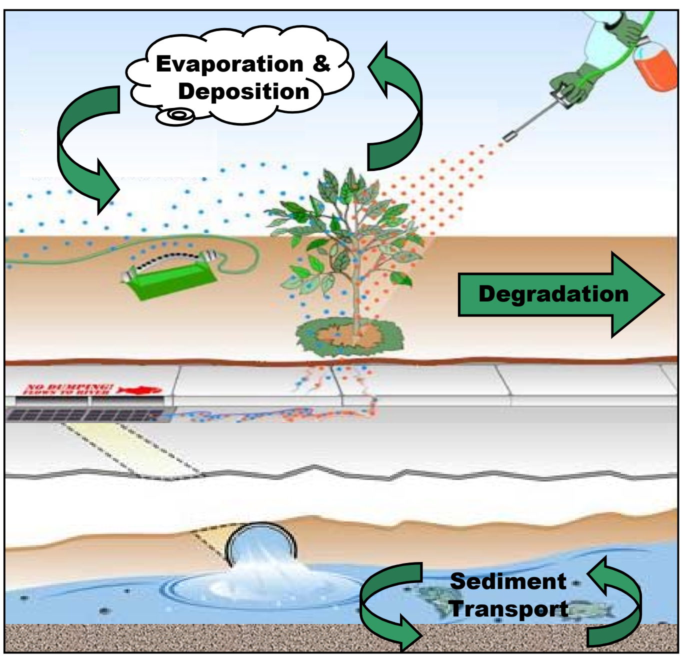

FIGURE 5.2*
Important Fate and Transport Processes, Particularly for Diazinon

*Figures are based on drawings prepared by University of California Statewide Integrated Pest Management Project.

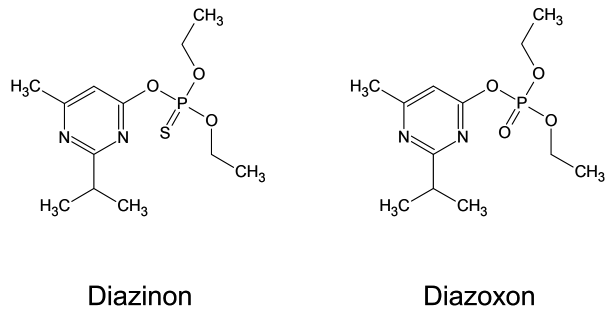

FIGURE 5.3
Diazinon and Diazoxon

degradation on land, within a creek it is a relatively unimportant degradation mechanism because of the relatively short residence time of storm water in urban creeks. Microbial activity is often the major route of diazinon degradation. Diazinon half-lives in soil range from 2 to 6 weeks. Under conditions of low temperature, low moisture, or high alkalinity, or conditions where microbial action is limited, however, the half-life may extend to 26 weeks or longer (Central Valley RWQCB 1993). Because microbial activity is more limited on paved surfaces than soil or plant surfaces, diazinon may degrade more slowly there (U.S. EPA 2000f). This may also be true for other pesticides.

Evaporation and Deposition

Diazinon's vapor pressure of 0.0001 torr (Novartis Crop Protection 1997) is relatively low. Because diazinon is not especially volatile, it tends to stay in soil or water rather than evaporate into the atmosphere. Diazinon can evaporate from surfaces (Glotfelty et al. 1990), however, particularly if these surfaces are impervious (Alameda County 2001). Spray applications result in losses to the atmosphere. When diazinon solutions are sprayed, part of the solution remains airborne and is deposited on nearby objects, such as buildings and roofs. In this way, diazinon can move through the air from surface to surface. During a rain event, diazinon on objects above the ground is washed back to the ground onto plants, soils, or paved surfaces subject to runoff.

Diazinon concentrations have been measured in over 50 samples of rain collected within the immediate vicinity of a diazinon application (Alameda County 2001). Most concentrations ranged from 100 to 1,000 nanograms per liter (ng/l, parts per trillion), but some of the samples contained as much as 15,000 ng/l diazinon. When rain samples were collected in 1995 without regard to the proximity of recent diazinon application sites, more than half did not contain detectable diazinon concentrations. Diazinon was detected in rain at eight locations, with concentrations ranging from 33 to 88 ng/l (SWRCB et al. 1997).

Diazinon evaporation and deposition may occur in urban areas, but much of the airborne diazinon probably deposits locally, typically within the same watershed where it was applied (Alameda County 2001). Since adjacent Bay Area urban watersheds are all considered impaired, in most cases, diazinon transported to nearby watersheds simply trades places with diazinon from these impaired watersheds. The potential for urban runoff to carry diazinon to an impaired water body remains the same. Wind may carry some airborne diazinon beyond the Bay Area to the Central Valley.

Sediment Transport

Diazinon tends to adhere more to organic matter than water. Its octanol-water partition coefficient, K_{ow}, is about 2,000, and its organic carbon-water partition coefficient, K_{oc}, is about 1,000 (Novartis Crop Protection 1997). It binds moderately well to soil, where it seldom migrates much below the top 0.5 inches (ETN 1996). Because of diazinon's affinity for particles, it may be deposited in the sediment of urban creeks. The movement of sediment may serve as a transport mechanism for diazinon within a creek (Chen et al. undated) and may also be an important diazinon sink.

Despite diazinon's tendency to adhere to particles, it is relatively soluble in water compared to the levels associated with toxicity. At room temperature, its solubility is about 40 milligrams per liter or 0.004% (Novartis Crop Protection 1997). This contributes to diazinon's mobility in runoff. A fraction of the diazinon in sediment may return to the water column. This may be an important process in stagnant pools and ditches that have high concentrations of diazinon in their sediment, or in creeks where water flows slowly over a long stretch of diazinon-laden sediment (ACCWP 1999a). The movement of pesticides such as diazinon between sediment and surface water is not fully understood.

QUANTITATIVE TRANSPORT MODEL

A quantitative transport model developed for a representative Bay Area watershed supports the conceptual model. It focuses on a well-defined watershed for which reliable long-term rainfall, flow, and water quality data are available.

In the context of diazinon in urban surface water, the best characterized watershed in the Bay Area is the Castro Valley Creek watershed. Alameda County has studied this watershed extensively and has modified a version of the U.S. Environmental Protection Agency Storm Water Management Model (EPA-SWMM) to simulate the fate and transport of diazinon in Castro Valley Creek (Alameda County 1999; Chen et al. undated). EPA-SWMM is designed to simulate pollutant loads, hydrology, and water quality in creeks. Alameda County has calibrated and verified the model for Castro Valley Creek using the data available for the watershed.

The watershed of Castro Valley Creek is representative of urban land use patterns in the Bay Area. The area is predominantly low-density residential neighborhoods (50%), with some open space (35%) and commercial development (15%) (ACCWP and Alameda County 1997). The Castro Valley Creek watershed covers an area of 5.5 square miles and is a sub-watershed of the San Lorenzo Creek drainage located in west central Alameda County (Chen et al. undated). The stream channel is mostly intact in the upper reaches, where it is surrounded primarily by open space. The central portions of the creek flow through channels and culverts through heavily developed land. The downstream portion of the channel is in a fairly natural state until it joins San Lorenzo Creek at the base of the watershed.

Alameda County's adaptation of EPA-SWMM is designed to simulate watershed processes over a two-year period. It estimates the application of diazinon on soil and impervious surfaces at monthly intervals and reduces diazinon accumulation through degradation. It tracks the amount of diazinon that washes off with rain and irrigation. The runoff rate corresponds to land use and has values distinguishing overland flow for urban (developed) and open space land uses (Chen et al. undated).

The model accounts for the buildup of pollutants on surfaces from air deposition, traffic, and human activity. For diazinon, human activity is the primary input and is adjusted to represent a per capita load of about 0.02 pounds per person (Alameda County 1997). The population of each sub-catchment is estimated on the basis of data compiled by the Alameda County Community Development Agency. This is combined with the per capita application rate to estimate the amount of diazinon entering the watershed. The monthly load is adjusted to represent seasonal changes in application rates. Difficulty in estimating actual diazinon application rates contributes substantially to uncertainty in the model results (Chen et al. undated).

Through a separate operation, the model simulates hydrologic processes, including rainfall, evaporation, surface discharge, and groundwater discharge. The hydrologic simulation is based on U.S. Geological Service flow data collected in Castro Valley Creek. The model has been calibrated with field data collected during the 1995-1996 wet season. It has subsequently been verified using 1996-1997 and 1999-2000 data (Chen et al. undated). Combined with the diazinon loads estimated from the application rate, degradation, and runoff assumptions, the hydrologic components of the model estimate diazinon concentrations in Castro Valley Creek.

To better match the observed data, a sediment transport module simulates erosion, suspension, transport, and deposition of particles. Linking diazinon with sediment substantially improves the model's simulation of diazinon concentrations. Therefore, the most important factors affecting the model appear to be seasonal loading, hydrologic flow, and sediment transport. The results of the quantitative model suggest that the conceptual model discussed above includes the processes most relevant to diazinon fate and transport from application sites to urban creeks.

KEY POINTS

The sources of diazinon and pesticide-related toxicity can be linked to the numeric targets proposed to protect the beneficial uses of Bay Area urban creeks. The initial release occurs during pesticide applications. Pesticides are then transported in surface runoff to storm drains during rain or irrigation events. Storm drains discharge runoff into urban creeks, where it causes toxicity. This conceptual pesticide transport model applies to all Bay Area urban creeks. A quantitative transport model developed for a representative watershed supports the conceptual model.

6. ALLOCATION SCHEME

From 1995 to 2000, about 85 tons of diazinon were applied each year in the nine Bay Area counties (CDPR 2001; CDPR 2000a; CDPR 2000b; CDPR 1999a; CDPR 1999b; CDPR 1996). However, only about 0.25% of the diazinon applied outdoors reaches urban creeks (ACCWP and Alameda County 1997). Therefore, the average annual combined diazinon load to all Bay Area urban creeks is roughly 400 pounds.

A "total maximum daily load" (TMDL) can be expressed as "mass per time," "toxicity," or any other appropriate measure, depending on the circumstances of the impairment. Pesticides such as diazinon impair urban creeks when their concentrations are high enough to be toxic to aquatic organisms. The mass of pesticides in a creek is immaterial as long as the concentration and toxicity targets are met. Therefore, this allocation scheme is expressed in terms of diazinon concentrations and toxicity (i.e., toxic units), just like the numeric targets.

ALLOCATION

TMDL allocations are divided among "waste load allocations" for point sources, "load allocations" for nonpoint sources, and any explicit "margin of safety."

TMDL = Waste Load Allocations + Load Allocations + Margin of Safety

The only significant source of diazinon in Bay Area urban creeks is urban runoff from storm drains. Storm drains are point sources; therefore, they must receive a waste load allocation. Because no significant nonpoint sources exist, no load allocations are proposed. For reasons discussed below, no explicit margin of safety is proposed either. Therefore, the only allocation is for urban runoff, and storm drains receive 100% of it. The discharge from each storm drain must meet the proposed numeric targets as the urban runoff enters its receiving water (the urban creek) if aquatic life is to be protected at all creek locations.

While the proposed allocation scheme appears simple, assigning responsibility for storm drains is complex. Municipal storm water management programs represent the communities that operate the storm drain systems and are responsible for storm drain discharges through National Pollutant Discharge Elimination System (NPDES) permits. However, local communities do not have full control over pesticide applications within their jurisdictions (see Section 6, Implementation Strategy). Many other parties also participate in urban pest management. Manufacturers make diazinon for formulators, who sell diazinon products to distributors and retailers, who in turn sell them to end users (see Section 2, Source Assessment). All these parties bear some responsibility for diazinon discharged through storm drains, and the TMDL implementation strategy involves all of them.

MARGIN OF SAFETY

A TMDL analysis involves uncertainty. To address this uncertainty, a TMDL is to include a margin of safety. It can be incorporated explicitly or implicitly or both. An explicit margin of safety would be provided by reserving a specific allocation for the margin of safety. This is not proposed; instead, this TMDL analysis includes an implicit margin of safety because it accounts for uncertainty, where necessary, by relying on a generally conservative approach. Moreover, the analysis involves relatively little uncertainty:

- ***Problem Statement.*** Some uncertainties relate to the problem statement. For example, more information could be gathered to characterize impaired creeks. However, uncertainties in defining the problem do not affect the ability to define an appropriate solution (i.e., identify sources, set numeric targets, and plan an implementation strategy).

- ***Source Assessment.*** There is relatively little uncertainty in identifying urban runoff as the primary source of diazinon in urban creeks. No other important sources exist.

- ***Numeric Targets.*** The proposed diazinon concentration targets were selected, in part, because they were the most protective choice available. They are water quality criteria developed by the California Department of Fish and Game using a standard protocol intended to protect most aquatic organisms most of the time. Proposing toxicity targets in addition to diazinon concentration targets inherently provides an added margin of safety. Shortcomings associated with the concentration targets (e.g., not accounting for chemical interactions or potential toxicity associated with replacement pesticides) are addressed by the toxicity targets.

- ***Linkage Analysis.*** The linkage between diazinon sources (storm drains) and the proposed targets (diazinon concentrations and toxicity in urban creeks) is straightforward and not subject to substantial uncertainty.

SEASONAL VARIATIONS AND CRITICAL CONDITIONS

Weather and seasons affect diazinon loads and concentrations. Because aquatic life beneficial uses are present in Bay Area urban creeks year-round, and because the *Water Quality Control Plan, San Francisco Bay Basin (Region 2)*'s toxicity objective protects these uses year-round, the proposed targets and allocation scheme are valid year-round. At times, the proposed targets are already met. At other times, the proposed targets are exceeded.

KEY POINTS

The "total maximum daily load" is allocated to one waste load: storm drains. The discharge from each storm drain must meet the proposed numeric targets as it enters the urban creek that receives the discharge. While this allocation scheme may appear simple, many parties bear responsibility for pesticide discharges through storm drains.

7. PESTICIDE OVERSIGHT

Various parties are responsible for pesticide discharges to urban creeks, and various parties oversee these activities. As illustrated on the left side of Figure 7.1, pesticide manufacturers supply pesticide users through product formulators, distributors, and retailers. The activities of these parties result in the pesticide discharges to urban creeks. As shown on the right side of Figure 7.1, an assortment of agencies and organizations oversee the diverse aspects of pesticide use. Each of these entities has a role to play in implementing the diazinon and pesticide-related toxicity TMDL.

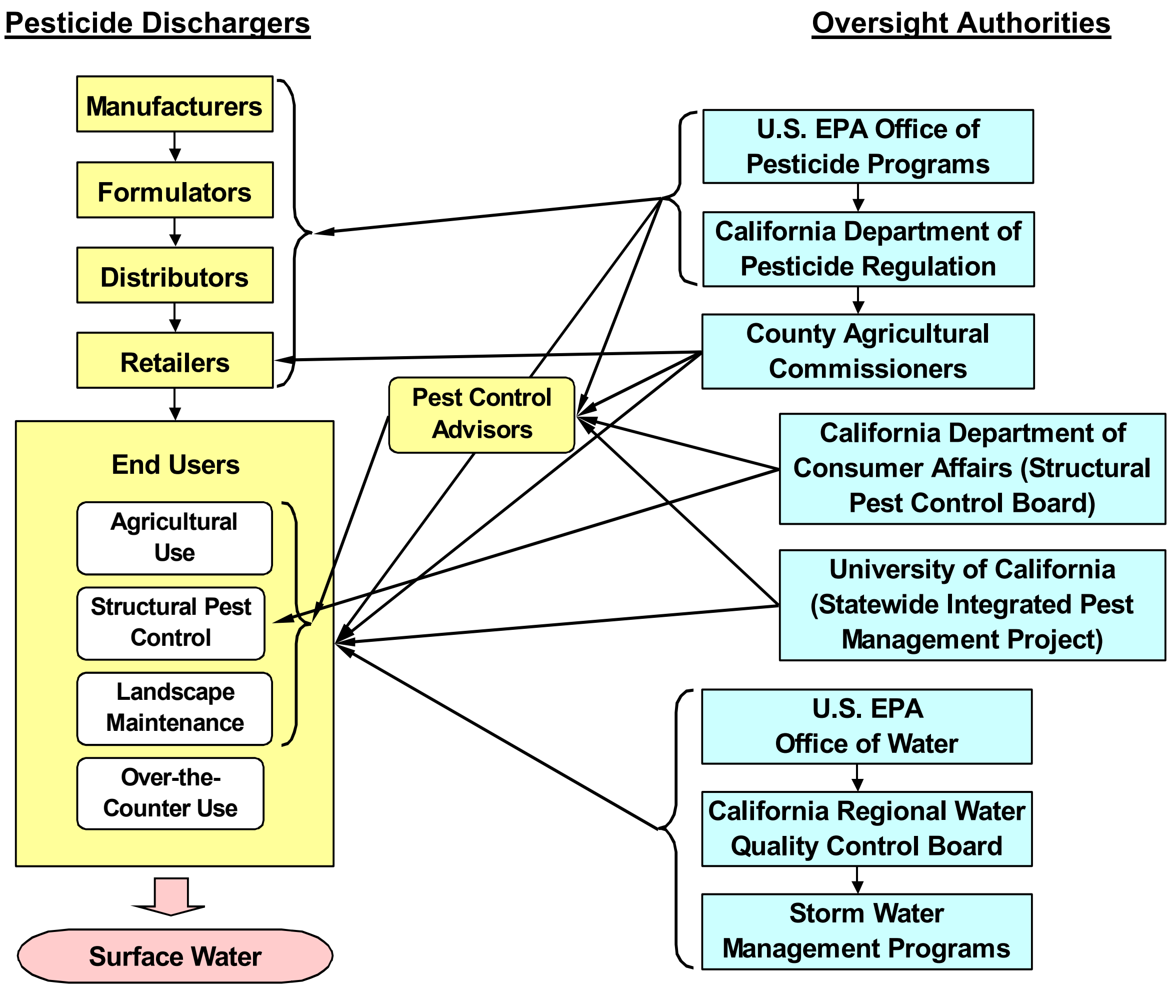

FIGURE 7.1
Oversight of Pesticide Dischargers

The agencies with the greatest implementation roles to play include the following:

- U.S. Environmental Protection Agency (U.S. EPA), including its Office of Pesticide Programs and Office of Water;

- California Environmental Protection Agency, including the San Francisco Bay Regional Water Quality Control Board (Regional Board), the State Water Resources Control Board (State Board), and the California Department of Pesticide Regulation (CDPR); and

- Bay Area municipal storm water programs and the municipalities they represent.

Others with implementation roles include County Agricultural Commissioners, the California Department of Consumer Affairs (i.e., the Structural Pest Control Board), and the University of California Statewide Integrated Pest Management Project.

U.S. ENVIRONMENTAL PROTECTION AGENCY

The U.S. EPA Office of Pesticide Programs is responsible for regulating all aspects of pesticide manufacture and use under the Federal Insecticide, Fungicide, and Rodenticide Act. Pesticide manufacturers and formulators must register their products with U.S. EPA. U.S. EPA requires that pesticide products be labeled with detailed instructions for their use. The labels name active ingredients, specify application instructions, provide warnings and first aid information, and describe appropriate storage and disposal procedures. Only U.S. EPA can approve pesticide label changes.

U.S. EPA evaluates the environmental fate and ecological effects of a pesticide when it is registered. U.S. EPA typically studies how a pesticide moves in surface water and groundwater following an application scenario, which is typically an agricultural application. U.S. EPA does not necessarily evaluate the fate and effects of pesticides as applied in urban areas, where applications on or near impervious surfaces are common.

The U.S. EPA Office of Pesticide Programs and Office of Water evaluate water quality effects differently. The differences stem from the Office of Pesticide Program's mandate to implement the Federal Insecticide, Fungicide, and Rodenticide Act and the Office of Water's mandate to implement the Federal Clean Water Act. These laws do not address potential environmental effects in the same manner. As a result, the Office of Pesticide Program's review does not necessarily ensure compliance with the Federal Clean Water Act as interpreted by the Office of Water. These offices have recently begun to work together to incorporate Federal Clean Water Act considerations into the registration process, beginning with the re-registration of the herbicide atrazine.

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

The State Board, the Regional Board, and CDPR operate within the California Environmental Protection Agency. The State Board and the Regional Board enforce California's Porter-Cologne Water Quality Control Act and portions of the Federal Clean Water Act. CDPR implements portions of California's Food and Agriculture Code and the Federal Insecticide, Fungicide, and Rodenticide Act.

California Department of Pesticide Regulation

CDPR regulates pesticide manufacture and use within California. It has authority over manufacturers, formulators, distributors, retailers, and end users, including professionals and those who apply over-the-counter products. CDPR regulations can be more stringent than U.S. EPA regulations. Although CDPR cannot change a U.S. EPA-approved pesticide label, it can restrict pesticide use in California by requiring a permit to apply a particular pesticide. The permit can include conditions, such as additional training requirements or special handling practices. The authority to enforce such permits is generally delegated to County Agricultural Commissioners.

CDPR has broad authority to regulate pesticides to protect water quality. Section 12824 of the California Food and Agriculture Code states:

> *The director [of CDPR] shall endeavor to eliminate from use in the state any pesticide that endangers the agricultural or nonagricultural environment…. Appropriate restrictions may be placed upon [a pesticide's] use including, but not limited to, limitations on quantity, area, and manner of application.*

Section 14102 of the California Food and Agriculture Code states:

> *The director shall prohibit or regulate the use of environmentally harmful materials….*

CDPR has broad discretion in what it considers environmental harm. Section 6158 of the California Code of Regulations (Title 3) states:

> *During the review and evaluation of proposed pesticide labeling and data to support registration, the director shall give special attention…to each of the following factors, when applicable, in reaching a decision to register or not register the pesticide:…*
>
> *(c) Potential for environmental damage, including interference with the attainment of applicable environmental standards (e.g., air quality standards and water quality objectives).*
>
> *(d) Toxicity to aquatic biota or wildlife….*

If any of these factors are anticipated to result in significant adverse impacts which cannot be avoided or adequately mitigated, registration will not be granted unless the director makes a written finding that anticipated benefits of registration clearly outweigh the risks.

To the extent that U.S. EPA may not have accounted for water quality standards in its pesticide registration process, CDPR can ensure that pesticides registered in California do not result in discharges that exceed water quality objectives. Any time CDPR receives evidence that a registered pesticide could adversely affect the environment, it can initiate a re-evaluation process. During re-evaluation, CDPR is authorized to request relevant information or studies from pesticide registrants. Based on the information it receives, it can restrict or ban pesticide applications in California. Re-evaluation and adoption of restrictions can take several years.

Water Boards

The State Board and, in the Bay Area, the Regional Board retain responsibility for enforcing water quality standards. The *Water Quality Control Plan, San Francisco Bay Basin (Region 2)* (Basin Plan) contains water quality objectives applicable to pesticide discharges and resultant aquatic toxicity (San Francisco Bay RWQCB 1995). Numeric targets developed through the TMDL process may be incorporated within the Basin Plan. The Porter-Cologne Water Quality Control Act (Water Code Section 13247) requires that all California agencies comply with the Basin Plan:

State offices, departments, and boards, in carrying out activities which may affect water quality, shall comply with water quality control plans approved or adopted by the state board unless otherwise directed or authorized by statute, in which case they shall indicate to the regional boards in writing their authority for not complying with such plans.

Pesticide-related impairment of Bay Area urban creeks pursuant to Federal Clean Water Act Section 303(d) demonstrates that pesticide levels are inconsistent with the Basin Plan. Diazinon specifically endangers the environment by posing environmental hazards to creeks, interfering with the attainment of water quality objectives, and exposing aquatic biota to toxicity. The TMDL process is a tool the Regional Board can use to ensure that urban creeks meet water quality standards.

Water Code Section 13225 places responsibilities on the Regional Board to:

(a) Obtain coordinated action in water quality control, including the prevention and abatement of water pollution and nuisance….

(c) Require as necessary any state or local agency to investigate and report on any technical factors involved in water quality control or to obtain and submit analyses of water; provided that the burden, including costs, of such

reports shall bear a reasonable relationship to the need for the report and the benefits to be obtained therefrom.

(d) Request enforcement by appropriate federal, state and local agencies of their respective water quality control laws….

The Regional Board has the authority to issue and enforce National Pollutant Discharge Elimination System (NPDES) permits for point-source discharges, including storm drains, pursuant to the Federal Clean Water Act. The Porter-Cologne Water Quality Control Act authorizes the Regional Board to issue and enforce Waste Discharge Requirements for point and non-point source discharges. The Regional Board can also waive Waste Discharge Requirements for certain discharges, while placing and enforcing conditions on such waivers. Regional Board enforcement tools include compliance orders, cease and desist orders, and clean-up or abatement orders.

MUNICIPAL STORM WATER PROGRAMS

Urban runoff flows through storm drain systems, which are point sources subject to NPDES permits. Therefore, the Regional Board directly oversees municipal storm water programs through its NPDES permit program. These permits require that discharges from storm drain systems not cause or contribute to violations of applicable water quality standards, including toxicity standards. Permit holders are required to reduce pollutant discharges to the maximum extent practicable. Section 122.26(d)(2)(iv) of the Code of Federal Regulations (Title 40) requires implementation of a program:

…to reduce, to the maximum extent practicable, pollutants in discharges from municipal separate storm sewers associated with the application of pesticides, herbicides and fertilizer which will include, as appropriate, control such as educational activities, permits, certifications and other measures for commercial applicators and distributors, and controls for application in public right-of-ways and at municipal facilities.

However, Section 11501.1 of the California Food and Agriculture Code significantly limits municipal authority to oversee pesticide applications by stating that most of these laws:

…are of statewide concern and occupy the whole field of regulation regarding the registration, sale, transportation, or use of pesticides to the exclusion of all local regulation. Except as otherwise specifically provided in this code, no ordinance or regulation of local government, including, but not limited to, an action by a local governmental agency or department, a county board of supervisors or a city council, or a local regulation adopted by the use of an initiative measure, may prohibit or in any way attempt to regulate any matter relating to the registration, sale, transportation, or use of pesticides, and any of these ordinances, laws, or regulations are void and of no force or effect.

These restrictions pose significant compliance liability for municipalities with storm water permits, wherein the municipalities are accountable for the presence of pesticides in their discharges but do not have the authority to regulate pesticide applications.

OTHERS WITH OVERSIGHT ROLES

Other organizations with oversight roles include County Agricultural Commissioners, the California Department of Consumer Affairs (i.e., Structural Pest Control Board), and the University of California Statewide Integrated Pest Management Project.

- ***County Agricultural Commissioners***. CDPR delegates certain authorities to County Agricultural Commissioners, including enforcement authority for pesticides applied professionally and pesticides sold over-the-counter. Bay Area counties with storm water permits may use the authorities vested in their County Agricultural Commissioners to minimize pesticide discharges.

- ***Department of Consumer Affairs***. The Structural Pest Control Board, which is within the Department of Consumer Affairs, is responsible for licensing structural pest control operators. The Structural Pest Control Board requires training and examinations to maintain a license to practice structural pest control.

- ***University of California Statewide Integrated Pest Management Project***. The University of California Statewide Integrated Pest Management Project is responsible for pest management education and outreach throughout California. Its advisors develop, demonstrate, and adapt effective pest management techniques and disseminate research-based pest management information. The University of California conducts regional outreach through its Cooperative Extensions.

KEY POINTS

The responsibility for protecting water quality lies with pesticide users and their suppliers (i.e., retailers, distributors, formulators, and manufacturers). A diverse array of agencies and organizations oversee various aspects of pesticide use. Each of these entities will play a role in implementing the diazinon and pesticide-related toxicity TMDL. Those with the broadest authorities include the U.S. Environmental Protection Agency and the California Environmental Protection Agency (including the Department of Pesticide Regulation and the Regional Board). Bay Area municipal storm water programs are responsible for storm drain discharges through NPDES permits, but they cannot prohibit or regulate the registration, sale, transportation, or use of pesticides.

8. IMPLEMENTATION STRATEGY

An implementation plan is needed to ensure that Bay Area urban creeks meet water quality standards for toxicity. The implementation strategy below describes actions to reduce pesticide discharges to urban creeks and achieve the numeric targets. As discussed below, the U.S. Environmental Protection Agency (U.S. EPA) has begun to phase out urban diazinon uses. These activities greatly influence the proposed implementation strategy. The strategy not only addresses diazinon and other pesticides currently contributing to aquatic toxicity in urban creeks, but it also addresses any potential water quality impacts posed by likely replacements. The singular intent of the implementation strategy is to ensure that Bay Area urban creeks attain the *Water Quality Control Plan, San Francisco Bay Basin (Region 2)*'s (Basin Plan's) water quality objective for toxicity.

DIAZINON PHASE-OUT PLANS

The Food Quality Protection Act enacted in 1996 requires U.S. EPA to reassess the risks associated with many pesticides, including diazinon. The law increases safety standards for pesticides and focuses special attention on children's health. To comply with the law, U.S. EPA recently undertook a new risk assessment for diazinon, focusing its attention on human health. The study found that all residential applications result in exposures that pose risks of concern. Following applications in residential areas, diazinon residue poses risks of concern for children. Many types of occupational exposures also pose risks of concern, and exposure to diazinon in drinking water could potentially pose a concern for infants and children (U.S. EPA 2000b).

The study concluded the following regarding environmental risks (U.S. EPA 2000f):

> *Because of diazinon's widespread use in the U.S., and documented widespread presence in water bodies at concentrations of concern to aquatic life, there is a high level of certainty that aquatic organisms will be exposed to potentially toxic levels of diazinon in surface water. Additionally, since diazinon and its major degradate oxypyrimidine are mobile and persistent in the environment, and found at significant levels in both ground and surface waters, it is quite probable that they will be available in quantity and for times that will exceed acute and chronic toxicity endpoints.*

As U.S. EPA released the study, Syngenta Crop Protection, the lead registrant for diazinon, announced it would phase out its urban diazinon sales (Syngenta 2000). Indoor uses would be phased out first. As of March 2001, manufacturers would no longer supply formulators with diazinon for indoor use products. Retail sales of products intended for indoor use would end December 3, 2002. Non-agricultural outdoor uses (e.g., home lawns, gardens, and other residential and non-agricultural uses) would be phased out more gradually. For these uses, manufacture of diazinon for product formulation would decrease by 50% or more by 2003. Diazinon would no longer be used to formulate products as of June 2003. Sales to retailers would end August 2003, and retail sales would end December 31, 2004. At that time, manufacturers would buy back all unsold retail products (U.S. EPA 2000c). Consistent with this agreement, U.S. EPA has begun the process of canceling registrations for some diazinon products.

Although some agricultural diazinon use, such as applications at greenhouses, may continue in some urban areas, U.S. EPA's action to eliminate nearly all urban diazinon use will reduce diazinon discharges to urban creeks. Eventually, diazinon levels in urban creeks will likely attain the proposed diazinon concentration targets. How long this will take is unknown. U.S. EPA will allow diazinon products sold over-the-counter prior to January 1, 2005 to be stored indefinitely and applied in accordance with their labels. Moreover, the persistence of diazinon in urban creeks, and particularly in the sediments of urban creeks, is poorly understood.

DIAZINON ALTERNATIVES

Conventional Pesticide Alternatives

Diazinon has long occupied a major portion of the pesticide market. Although U.S. EPA's actions will eliminate most urban diazinon uses, phasing out diazinon could increase reliance on alternative pesticides and encourage new pesticides to enter the marketplace. Replacement pesticides could steadily increase their market share by fulfilling the perceived needs of pesticide consumers. Diazinon alternatives may inadvertently pose some new water quality risks. Malathion and carbaryl are readily available alternatives that kill pests in the same manner as diazinon; they inhibit acetylcholinesterase (CDPR 2001b). Imidacloprid, a relatively new alternative, is very soluble in water (TDC 2002).

Pyrethroids are the most rapidly growing class of diazinon replacements. They include bifenthrin, cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, and permethrin, among others. As a group, pyrethroids exhibit low water solubility, low volatility, and high octanol-water partition coefficients (K_{ow}). For these reasons, they are relatively immobile in soil, and they strongly bind to sediment. When discharged into surface water, they tend to quickly disappear from the water column (Laskowski 2002), but they can persist in sediment for months (Weston 2002).

Pyrethoids are toxic to invertebrates and fish at concentrations as low as 6 nanograms per liter (ng/l, parts per trillion). Depending on the specific pyrethroid tested, concentrations ranging from 90 ng/l to 700 ng/l are toxic to 50% of *Ceriodaphnia dubia* test organisms (Miller et al. 2002). At concentrations of 4 ng/l, the pyrethroid cypermethrin inhibits the ability of male Atlantic salmon to smell a female pheromone. When salmon sperm and eggs are exposed at 100 ng/l, cypermethrin reduces the number of fertilized eggs (Moore and Waring 2001). The potential for pyrethroids to contribute to sediment toxicity is unknown.

The growing use of pyrethroids also poses analytical challenges. Because pyrethroids are nearly insoluble in water, they bind strongly to any type of surface, including the surfaces of test containers and equipment (Laskowski 2002). Analytical procedures able to detect pyrethroids at ecologically relevant concentrations are generally inadequate. Moreover, no published procedures for conducting Toxicity Identification Evaluations exist; therefore, identifying pyrethroids as the cause of any toxicity that could relate to them is difficult (Miller et al. 2002).

Because the conventional pesticide alternatives likely to replace diazinon pose substantial potential risks to water quality, this implementation strategy needs to account for and respond to these risks, so as to avoid solving one problem and causing another.

Integrated Pest Management

Substituting the discharge of one conventional pesticide for another could be counterproductive, particularly if the replacement pesticide could cause aquatic toxicity. To address any potential new risks, this plan's over-arching strategy for reducing the adverse effects of diazinon and other pesticides in urban runoff is to discourage the use of conventional pesticides that threaten water quality. This strategy prevents pesticide discharges at their source.

One way to reduce the use of conventional pesticides that threaten water quality is to practice Integrated Pest Management (IPM). The University of California Statewide Integrated Pest Management Project defines IPM as follows (UC IPM 2001):

> *Integrated pest management…is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment.*

The Bio-Integral Resource Center offers a similar definition (BIRC 2001):

> *Integrated pest management… is an approach to pest control that utilizes regular monitoring to determine if and when treatments are needed and employs physical, mechanical, cultural, biological and educational tactics to keep pest numbers low enough to prevent unacceptable damage or annoyance. Least-toxic chemical controls are used as a last resort.*

The U.S. Environmental Protection Agency Office of Pesticide Programs describes IPM as follows (U.S. EPA 2001):

> *The IPM system consists of four steps: (1) set action thresholds; (2) monitor and identify pests; (3) prevent pests; and (4) control pests when necessary.*

IPM techniques are effective. They can reduce the potential for pesticide discharges to occur, while minimizing the potential to create new risks by not necessarily replacing one conventional pesticide with another. As an illustrative example, Table 8.1 describes an IPM approach for managing ants. In a survey of Bay Area pest management practices, ants were the most frequently reported pest problem (Alameda County 1997).

TABLE 8.1
Typical IPM Approach for Managing Ants

Step	Activity
1. Set Action Thresholds	Ants serve important ecological functions. Some ants should be tolerated outdoors. Action may be required when ants come indoors.
2. Monitor and Identify Pests	Common Bay Area ants include Argentine ants and carpenter ants. These ants look different and require different management strategies. Similarly, individual "scouts" require a different management strategy than a major infestation.
3. Prevent Pests	Good hygiene practices (e.g., storing food in sealed containers and keeping areas clean and dry) are effective in preventing Argentine ant infestations. Entry points along walls, moldings, and baseboards, and in gaps around pipes and ducts, can be effectively blocked with petroleum jelly, tape, or caulk.
4. Control Pests When Necessary	Non-toxic ant control methods are effective. Individual "scouts" can be killed by hand. Ant trails can be cleaned with a vacuum or soapy water. Soap also washes away the chemical trail ants follow. As a last resort, pesticides can be used, but low toxicity baits are available that minimize pesticide use and confine the pesticide to a very small, contained area.

IMPLEMENTATION ACTIONS

Primary Goals

The implementation plan is to ensure the successful attainment of the proposed numeric targets, which relate to diazinon concentrations and aquatic toxicity. As shown in Figure 8.1, the plan focuses on three areas: proactive regulation, education and outreach, and research and monitoring. Table 8.2 lists specific goals for each of these areas.

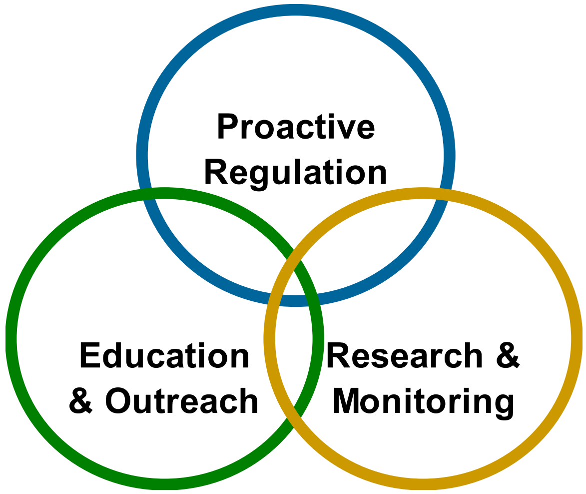

FIGURE 8.1
Areas of Focus for Implementation

TABLE 8.2
Primary Implementation Strategy Goals

Area of Focus	Goals
Proactive Regulation	• Pesticides will be regulated to ensure compliance with all applicable pesticide and water quality laws and regulations, including the Federal Insecticide, Fungicide, and Rodenticide Act, the California Food and Agriculture Code, the Federal Clean Water Act, and California's Porter-Cologne Water Quality Control Act. • Pesticide applications will not result in pesticide concentrations in urban creeks that are lethal to or that produce detrimental responses in aquatic organisms, including chronic and acute effects.
Education and Outreach	• Private and public entities will minimize their reliance on conventional pesticides to reduce potential toxicity associated with pesticide discharges. • Private and public entities will adopt least toxic pest management practices (i.e., including Integrated Pest Management). • Education and outreach programs will target municipal operations, professional applications (e.g., structural pest control, landscape maintenance, and agriculture), and consumer use of over-the-counter products, and convince all public and private entities to practice least toxic pest management.
Research and Monitoring	• Monitoring will demonstrate that diazinon concentrations in urban creeks meet numeric targets. • Monitoring will demonstrate that Bay Area urban creeks meet toxicity targets. • Ongoing studies will ensure that diazinon replacements, including those currently available for sale and those yet to enter the marketplace, will meet toxicity targets and not pose substantial water quality risks. • Studies will be completed as needed to foster proactive pesticide regulation and effective education and outreach programs.

Actions

The role of the Regional Board is to encourage, monitor, and enforce implementation activities, and to lead by example. The Regional Board will consider taking the specific actions listed in Table 8.3. The Regional Board will also work with others responsible for pesticide use and oversight to encourage or require them to implement the proposed actions listed in Table 8.4. The actions proposed in Table 8.4 are preliminary. Some involve new efforts or enhancements to existing activities. The Regional Board will work with each organization to evaluate these proposals in terms of opportunities and constraints, including regulatory authorities and resource limitations.

To ensure that the actions assigned to U.S. EPA, the California Department of Pesticide Regulation, County Agricultural Commissioners, the California Department of Consumer Affairs, and the University of California Statewide Integrated Pest Management Project are implemented, the Regional Board will rely on inter-agency cooperation. Actions assigned to pesticide manufacturers and formulators, retailers, and pest control advisors and operators are proposed to be voluntary. The Regional Board will exercise its direct authority to require municipal storm water programs to undertake the actions called out for them in Table 8.4 pursuant to National Pollutant Discharge Elimination System (NPDES) permits. Although municipalities do not have the authority to regulate pesticide applications, they can implement a number of actions, as shown in Figure 8.2. Many municipalities are already implementing these actions.

In Tables 8.3 and 8.4, actions specifically focusing on diazinon, such as U.S. EPA's phase-out actions and municipal efforts to reduce diazinon use, will address the diazinon concentration targets. The more general actions focused on reducing the use of pesticides that threaten water quality will address the toxicity targets.

TABLE 8.3
Regional Board Actions

Area of Focus	Action
Proactive Regulation	1. Monitor U.S. EPA pesticide evaluation and registration activities as they relate to surface water quality.
	2. Share with U.S. EPA monitoring and science data generated within the Bay Area.
	3. When necessary, request that U.S. EPA coordinate competing aspects of the Federal Insecticide, Fungicide, and Rodenticide Act and the Federal Clean Water Act, and encourage U.S. EPA to accommodate water quality concerns within its pesticide registration process.
	4. Work with the California Department of Pesticide Regulation (CDPR) to develop and implement a strategy to ensure that all pesticide applications in California comply with the Federal Clean Water Act and the Porter-Cologne Water Quality Control Act as set forth in the Basin Plan.

Area of Focus	Action
	5. Interpret federal and state water quality standards applicable in the Bay Area to assist CDPR.
	6. Work with CDPR to assemble information (such as monitoring data), as requested, for it to take necessary action.
	7. Incorporate within municipal storm water NPDES permits necessary requirements to actively support pesticide regulatory actions that protect water quality.
	8. Enforce NPDES permit provisions related to pesticide discharges.
Education and Outreach	9. Incorporate within municipal storm water NPDES permits necessary requirements to adopt least toxic management practices (such as IPM) within municipal operations and to promote such practices within local and regional communities.
	10. Work with County Agricultural Commissioners; the Department of Consumer Affairs; the University of California Statewide Integrated Pest Management Project; pesticide manufacturers, formulators, distributors, and retailers; and pesticide users to encourage least toxic pest management practices such as IPM.
	11. Develop tools for evaluating and tracking the success of education and outreach programs.
	12. Encourage grant funding for activities likely to reduce pesticide discharges, promote least toxic pest management practices, or otherwise further the goals of this implementation strategy.
	13. Encourage pilot demonstration projects that show promise for reducing pesticide discharges throughout the Bay Area.
Research and Monitoring	14. Support the development of publicly available and commercially viable analytical methods to detect ecologically relevant concentrations of the pesticides replacing diazinon that pose the greatest water quality risks. Proprietary information provided to U.S. EPA and CDPR may not be useful for public monitoring efforts.
	15. Support the development of Toxicity Identification Evaluation procedures that can be used to identify potential toxicity in surface water and sediments.
	16. Promote the completion of publicly available studies that characterize the fate and transport of pesticides applied in urban areas.
	17. Promote the development and adoption of evaluation methods (e.g., quantitative fate and transport models) for urban pesticide applications, including applications to impervious surfaces.
	18. Promote the completion of publicly available studies to support the development of water quality criteria for pesticides in the water column and sediment.
	19. Incorporate within municipal storm water NPDES permits necessary requirements to characterize conditions in urban creeks.

TABLE 8.4
Actions by Others

Organization	Actions
U.S. Environmental Protection Agency	1. Phase out most urban diazinon uses, as planned.
	2. If the phase-out does not result in the attainment of the diazinon concentration targets, then take additional steps to reduce diazinon runoff.
	3. To address likely shifts in the pesticide marketplace resulting from the diazinon phase-out, and the potential for these shifts to pose new water quality risks, continue coordination between the Office of Pesticide Programs and Office of Water to ensure that pesticide applications comply with water quality standards.
	4. Support the development of publicly available and commercially viable analytical methods to detect ecologically relevant concentrations of the pesticides replacing diazinon that pose the greatest water quality risks.
	5. Support the development of Toxicity Identification Evaluation procedures that can be used to identify potential toxicity in surface water and sediments.
	6. Promote the completion of publicly available studies that characterize the fate and transport of pesticides applied in urban areas.
	7. Promote the development and adoption of evaluation methods (e.g., quantitative fate and transport models) for urban pesticide applications, including applications to impervious surfaces.
	8. Promote the completion of publicly available studies to support the development of water quality criteria for pesticides in the water column and sediment.
California Department of Pesticide Regulation	9. Adopt a process to address pesticide-related surface water impairment. CDPR has already prepared a draft process (CDPR 2002).
	10. Work with the Regional Board to identify likely diazinon replacements and study the likelihood that foreseeable applications in urban areas could result in runoff that exceeds water quality standards (e.g., study the fate and transport of higher risk pesticides specifically within the urban environment, focusing especially on pesticides sold over-the-counter and pesticides applied to impervious surfaces).
	11. If necessary to meet water quality standards, use existing enforcement authorities to adopt regulations, direct registrants to mitigate potential water quality concerns, designate certain pesticides as restricted materials subject to permit conditions, or refuse or cancel registrations.
	12. Continue and enhance education and outreach programs to encourage least toxic pest control, including IPM.
	13. Continue to support the completion of publicly available studies that characterize the fate and transport of pesticides applied in urban areas.
	14. Work with the Regional Board to promote the development and adoption of evaluation methods (e.g., quantitative fate and transport models) for urban pesticide applications, including applications to impervious surfaces.

Organization	Actions
	15. Work with the Regional Board to support the development of publicly available and commercially viable analytical methods to detect ecologically relevant concentrations of the pesticides replacing diazinon that pose the greatest water quality risks.
	16. Work with the Regional Board to support the development of Toxicity Identification Evaluation procedures that can be used to identify potential toxicity in surface water and sediments.
	17. Work with the Regional Board to promote the completion of publicly available studies to support the development of water quality criteria for pesticides found in the water column and sediment.
Municipal Storm Water Programs	18. Develop and implement plans to support pesticide regulatory actions that protect water quality, to adopt least toxic management practices (such as IPM) within municipal operations and promote such practices within local and regional communities, and to characterize conditions within urban creeks receiving pesticide runoff. (See Figure 8.2.) Many municipalities are already implementing these activities in accordance with their municipal storm water permits.
	19. Equitably share among municipalities the burden of developing and implementing plans to eliminate pesticide-related toxicity in urban creeks.
	20. Reduce municipal reliance on pesticides that threaten water quality by adopting policies, procedures, or ordinances that minimize the use of conventional pesticides in municipal operations and on municipal property. Section 11501.1 of the California Food and Agriculture Code does not prohibit municipal policies, procedures, or ordinances seeking only to control a municipality's own participation in the pesticide marketplace.
	21. Track the progress of municipalities by periodically reviewing their pesticide use and the use of pesticides by the contractors they hire.
	22. Train municipal employees to use IPM techniques and require that they adhere to IPM practices.
	23. Require municipal contractors to practice IPM.
	24. Undertake targeted outreach programs to encourage communities to reduce their reliance on conventional pesticides that threaten water quality. Educate municipal employees (whether or not they apply pesticides as part of their work responsibilities), local businesses (e.g., restaurants), pest control operators, landscape gardeners, and the public at large. Focus efforts on the audiences most likely to use pesticides that threaten water quality (e.g., owner-occupied single-family residences and structural pest control operators). Many municipalities conduct effective outreach at the point-of-sale, where many pest management decisions are made.
	25. Encourage appropriate pesticide waste disposal. As U.S. EPA cancels diazinon registrations, encourage individuals to dispose of their supplies instead of risking environmental release.
	26. Require pest-resistant landscaping at new development and re-development sites, minimize impervious surfaces at these sites, and encourage landscape designs that tend to delay runoff entering nearby creeks.

Organization	Actions
	27. Monitor diazinon and toxicity in urban creeks, and other pesticides as needed; investigate toxicity in both the water column and in sediment.
	28. Share with U.S. EPA monitoring and science data generated.
	29. Monitor U.S. EPA pesticide evaluation and registration activities as they relate to surface water quality.
	30. When necessary, request that U.S. EPA coordinate competing aspects of the Federal Insecticide, Fungicide, and Rodenticide Act and the Federal Clean Water Act, and encourage U.S. EPA to accommodate water quality concerns within its pesticide registration process.
	31. Work with CDPR to develop and implement a strategy to ensure that all pesticide applications in California comply with the Federal Clean Water Act and the Porter-Cologne Water Quality Control Act as set forth in the Basin Plan.
	32. Work with CDPR to assemble information (such as monitoring data), as requested, for it to take necessary action.
	33. Identify and report to CDPR and County Agricultural Commissioners violations of pesticide regulations by others.
County Agricultural Commissioners	34. Continue and enhance enforcement related to overuse and misuse use of pesticides, including pesticides sold over-the-counter.
	35. Continue to coordinate with and contribute to education and outreach efforts undertaken by municipal storm water programs and others.
	36. Continue to enforce the phase out of diazinon products and any new regulations affecting pesticide applications and their water quality risks.
California Department of Consumer Affairs	37. Work with the Regional Board and CDPR to require additional initial IPM training and additional continuing IPM training for all structural pest control licensees.
UC Statewide Integrated Pest Management Project	38. Continue and enhance educational efforts targeting urban pesticide uses to promote least toxic pest management practices such as IPM.
	39. Continue to encourage and support efforts to identify and perfect new IPM strategies for the urban environment.
Pesticide Manufacturers and Formulators	40. Minimize potential pesticide discharges by developing and marketing products designed to avoid discharges that exceed water quality objectives. Many manufacturers successfully market such products.
	41. Support the development of publicly available and commercially viable analytical methods to detect ecologically relevant concentrations of the pesticides replacing diazinon that pose the greatest water quality risks.
	42. Develop and make publicly available commercially viable methods to detect pesticide-related toxicity in surface water, including Toxicity Identification Evaluation procedures that can be used to identify potential toxicity in surface water and sediments.
	43. Complete and make publicly available studies that characterize the fate and transport of pesticides applied in urban areas.

Organization	Actions
	44. Develop evaluation methods (e.g., quantitative fate and transport models) for urban pesticide applications, including applications to impervious surfaces.
	45. Complete and make publicly available studies to support the development of water quality criteria for pesticides in the water column and sediment.
Pesticide Retailers	46. Offer point-of-sale information on IPM and less toxic alternatives, and promote these alternatives to customers by offering alternatives for sale.
Pest Control Advisors	47. Recommend IPM strategies so conventional pesticides are used only as a last resort.
Pest Control Operators	48. Adopt IPM techniques and promote them to customers so pesticide applications do not contribute to pesticide runoff and toxicity in urban creeks.

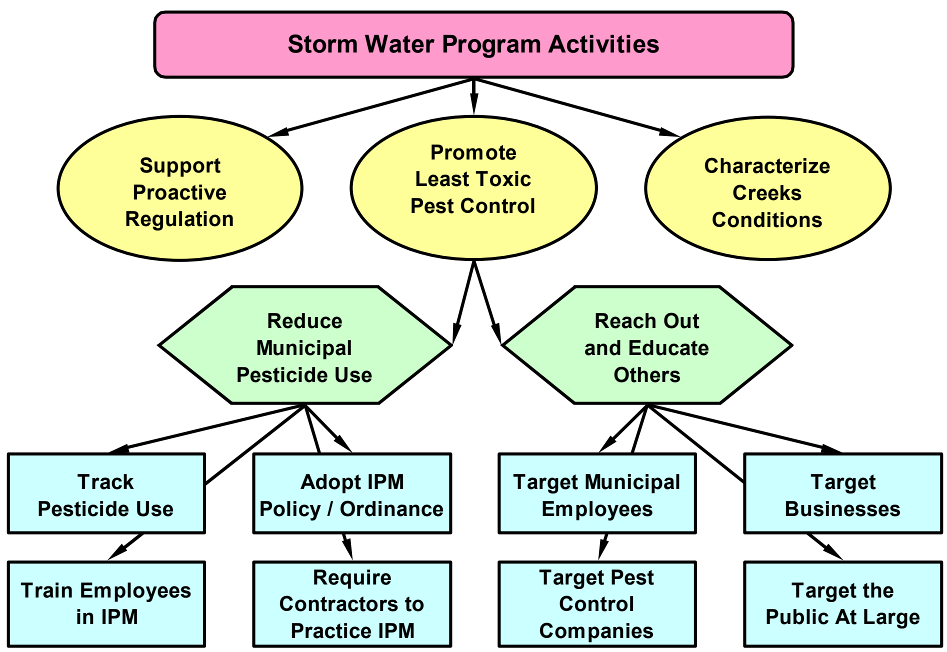

FIGURE 8.2
Municipal Activities

MONITORING AND ADAPTIVE MANAGEMENT

Municipal storm water permits require dischargers to characterize their discharges, which necessarily involves monitoring diazinon concentrations and aquatic toxicity. The Regional Board will use this information to track progress in implementing this TMDL. Diazinon concentrations will be monitored until urban creeks attain the proposed numeric targets for diazinon concentrations. Water quality monitoring will seek to answer the following questions:

- Are actions being taken to reduce pesticide discharges and their associated toxicity making a positive difference?
- Are diazinon concentrations decreasing to levels below the numeric targets?
- Do standard toxicity tests indicate that toxicity in urban creeks is still a problem?
- If so, what are the causes of the toxicity?
- Do pesticides other than diazinon pose any water quality concerns?

If water quality monitoring demonstrates that implementing this strategy is not resulting in the attainment of the proposed targets, the Regional Board may reconsider and possibly revise the strategy to offer more effective protection for the aquatic life of the Bay Area's urban creeks.

Because new pesticides are expected to continue to become available, the need to monitor aquatic toxicity within the water column and sediment is expected to remain well after the diazinon concentration target is achieved. Substantial exceedances of the toxicity target will trigger the need for Toxicity Identification Evaluations to determine the causes of the toxicity. Pesticide-related toxicity will be subject to implementation actions identified for this TMDL. If this strategy were to prove inadequate, additional measures could need to be identified and implemented. Toxicity related to stressors other than pesticides could warrant further study, but would be beyond the scope of this TMDL.

As the pesticide market changes (e.g., due to the diazinon phase-out), replacement pesticides may begin to show up in urban creeks. Monitoring programs may need to investigate the potential presence of these pesticides in surface water. Such monitoring data could inform pesticide registration and re-registration decisions being made by U.S. EPA. Monitoring pesticides that are increasing their urban market share may be very useful to U.S. EPA as it determines the potential water quality impacts of these pesticides.

To track progress in implementing the diazinon and pesticide-related toxicity TMDL, the Regional Board will monitor the activities of the various parties identified in the implementation plan, including U.S. EPA, the California Department of Pesticide Regulation, municipal storm water programs, and others. It will also monitor its own actions.

KEY POINTS

The over-arching strategy for reducing the effects of diazinon in urban runoff will be to avoid the use of conventional pesticides that threaten water quality through the application of IPM techniques and the use of least toxic pesticides. The strategy focuses on proactive regulation, education and outreach, and research and monitoring. Implementation of the strategy is expected to achieve the proposed numeric targets and protect aquatic life beneficial uses. Implementation monitoring and water quality monitoring will confirm that the strategy is working.

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