HUMAN HEALTH EFFECTS AND WILDLIFE EFFECTS OF ENVIRONMENTAL ESTROGENS

SANTA ROSA SUBREGIONAL LONG-TERM WASTEWATER PROJECT

Prepared for

City of Santa Rosa

and

U.S. Army Corps of Engineers

September 1995

Prepared by

PARSONS ENGINEERING SCIENCE, INC.
PLANNING · DESIGN · CONSTRUCTION MANAGEMENT
1301 MARINA VILLAGE PARKWAY, ALAMEDA, CA94501 · 510/769-0100
OFFICES IN PRINCIPAL CITIES
723129/94-03

for

HARLAND BARTHOLOMEW AND ASSOCIATES, INC.

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1 INTRODUCTION

A large number of the man-made, industrial and agricultural chemicals that have been released into the environment over the past 50 years have been suggested as having the potential to disrupt the endocrine system of terrestrial and aquatic life. Some of these chemicals and pollutants comprise the environmental estrogens or "xenoestrogens," which may disrupt biological processes by mimicking the effects of naturally produced hormones such as the female hormone estrogen. The potential xenoestrogens include organochlorine chemicals (e.g., DDT, dioxins, polychlorinated biphenyls), alkylphenolic compounds, and synthetic estrogens. These chemicals and their effects on the health of humans and wildlife have received a great deal of coverage in both the popular media and the scientific literature (Begley and Glick 1994; Colborn and Clement 1992; Colborn, et al. 1993; Cotton 1994; Farrow 1994; Great Lakes Natural Resource Center 1994; Jobling and Sumpter 1993; Raloff 1994; Schmidt 1994; Sharpe 1992; Stone 1994).

It has recently been recognized that some of these chemicals (e.g., dioxins, metabolites of DDT) may mimic and/or disrupt the activity of the male sex hormones, the androgens (Raloff 1995). For the purpose of this report the chemicals will be referred to as potential environmental estrogens or xenoestrogens, although a broader term, such as environmental hormone or hormone-mimic may be more appropriate.

The purpose of this technical report is to identify the chemicals currently reported to be potential environmental estrogens and to review and summarize the current scientific literature that discusses the effects of these chemicals on the health of humans and wildlife. Concern has been expressed at public meetings and workshops for the Santa Rosa Subregional Long-Term Wastewater Project (the Subregional Wastewater Project) that potential environmental estrogens may be present in reclaimed water from the Laguna Wastewater Treatment Plant (the Laguna Plant) at concentrations that may affect the health of humans and wildlife that come in contact with this water. Although the Laguna Plant would not be expected to generate potentially estrogenic chemicals, it is possible that the wastewater treatment process could transform some chemicals in the influent to potentially estrogenic compounds or it may release in its effluent some fraction of the potential environmental estrogens entering the plant from household, commercial, and industrial dischargers (see Section 2).

Concurrent with the preparation of this report, a reclaimed water quality study is being conducted for the Subregional Wastewater Project to measure concentrations of many common chemicals that may be in the wastewater discharged from the Laguna Plant and in the Russian River upstream from its confluence with Mark West Creek (and thus not under the influence of discharges from the Laguna Plant). In addition, many chemicals have been (and continue to be) measured as part of the Laguna Plant's National Pollutant Discharge Elimination System (NPDES) quarterly water monitoring program. Some of the chemicals in the reclaimed water quality study and the quarterly water monitoring program are identified in this report as potential environmental estrogens. However,

because the lists of chemicals to be analyzed for the reclaimed water quality study and the quarterly water monitoring program were determined prior to the preparation of this report, the analytical methods for these programs were not designed to detect potential environmental estrogens. This report identifies which potential environmental estrogens have (or have not) been analyzed as part of the reclaimed water quality study or the quarterly water monitoring program.

The analytical results from the reclaimed water quality study will be presented in the Reclaimed Water Quality Technical Report. The analytical results from the reclaimed water quality study and the quarterly water monitoring program also will be used in a screening human health risk assessment and a screening ecological risk assessment, the results of which will be presented in separate risk assessment reports.

This technical report is divided into six sections. Section 2 follows this introduction and defines the estrogenic effect. It also describes the classes of chemicals that are reported to be environmental estrogens and identifies their sources and fate in the environment. Section 3 summarizes the scientific evidence for the health effects of environmental estrogens on humans and Section 4 summarizes the evidence for these effects on wildlife. Sections 3 and 4 also identify the relative effectiveness of the various chemicals to produce estrogenic effects, where such information is available. Section 5 is a summary. Section 6 is a list of references.

2 THE ESTROGENIC EFFECT

This section briefly describes the endocrine system of vertebrates (animals with backbones) and how it is regulated. It also defines "estrogenic effects" and describes the classes of man-made and natural chemicals that have been implicated in producing these effects.

THE ENDOCRINE SYSTEM AND THE ESTROGENIC EFFECT

Many metabolic processes in animals are under the control of the endocrine system, a group of organs (endocrine glands) that produce and secrete hormones. Secreted hormones travel through the blood circulatory system from the endocrine glands to their target gland or tissue. When the hormones reach their destination, they are recognized by specific receptors on cell surfaces within the target organs or tissues. The hormones bind to these receptors and exert their influence at the cellular surface or they pass across the outer cellular membrane and exert their influence within the cell, usually by affecting gene expression. By affecting gene expression, the hormones play an important role in regulating metabolism and development on both a cellular and an organismal level.

The endocrine system regulates many of the processes associated with sexual reproduction and development, such as the estrous cycle of females and the development of the primary and secondary sexual characteristics of both males and females. These processes are primarily regulated by the sex hormones, including estrogen, progesterone and testosterone. The sex hormones are steroid hormones that are chemically derived from cholesterol and synthesized in the sexual organs of animals. Estrogen and progesterone are synthesized in the ovaries of females while testosterone, an androgen, is produced in the testes of males. When the sex hormones reach a target organ or tissue they enter cells and their nuclei, where they initiate the transcription of some genes while repressing the transcription of others. A typical process in mammals that is under the control of the endocrine system is lactation, the production of milk by the mammary glands of nursing females. Lactation is controlled by the blood levels of estrogen and progesterone, which in turn affect the production of two other hormones, prolactin, which is secreted by the pituitary gland, and oxytocin, which is produced by the hypothalamus. In breast cells prolactin induces the production of milk while oxytocin stimulates its secretion.

It has been suggested that some man-made and natural chemicals disrupt this delicately balanced system of hormonal regulation. This disruption may be manifested in humans or wildlife as a decrease in fertility (e.g., reduced sperm production), an increase in birth defects, altered sexual expression or an increase in certain cancers (e.g., breast cancer and testicular cancer). Collectively these adverse outcomes of exposure to environmental estrogens are referred to as "estrogenic effects."

It has been postulated that environmental estrogens may induce their effects by (1) mimicking the effects of natural hormones by recognizing their binding sites; (2) antagonizing the effects of natural hormones by blocking their interaction with their physiological binding sites; (3) reacting directly or indirectly with hormones; (4) altering the natural pattern of synthesis of hormones; or (5) altering hormone receptor levels (Colborn and Clement 1992, Schmidt 1994). There are, therefore, many potential points at which hormone activity could be disrupted. This is one reason why a relatively large and diverse group of chemicals has been identified as potential environmental estrogens (Table 1). These chemicals include organochlorine compounds such as pesticides [e.g., dichlorodiphenyltrichloroethane (DDT) and its degradation products; chlordane; and 2,4-dichlorophenoxyacetic acid (2,4-D)], polychlorinated biphenyls (PCBs), and dioxins (e.g., 2,3,7,8-tetrachlorodibenzo-*p*-dioxin); triazine herbicides; carbamate pesticides; alkylphenolic compounds (e.g., laundry and dishwashing detergents and wetting agents); synthetic estrogens; and metals (Colborn et al. 1993). This list of chemicals may continue to grow as science broadens the definition of the phenomenon to include effects on the activity of male sex hormones (Raloff 1995). While most potential environmental estrogens are only weakly estrogenic compared to the natural and synthetic estrogens (see Sections 3 and 4), the widespread former use of organochlorine compounds, such as DDT and PCBs, and the current use of alkylphenolics (in detergents), combined with their persistence in the environment has raised concern that these chemicals may have adverse effects on wildlife and human populations (Colborn and Clement 1992).

The following section describes the sources, uses and environmental fates of some of the more common and extensively studied of these chemicals. Unless otherwise indicated, this information was obtained from the National Library of Medicine's Hazardous Substances Database (HSDB) and the United States Environmental Protection Agency's Integrated Risk Information System (IRIS). Both information sources are available on the National Library of Medicine's data network system (TOXNET).

POTENTIAL ENVIRONMENTAL ESTROGENS

With the exception of synthetic estrogens (e.g., compounds used in birth control pills and for hormone therapy) the primary commercial and industrial uses of the chemicals that have been identified as potential environmental estrogens have been unrelated to their estrogenic effects. Organochlorine, triazine and carbamate pesticides have been widely used to control insect, plant and fungal pests, PCBs have been used primarily as coolants, lubricants and electrical insulators, and alkylphenolic compounds are commonly used in household and commercial detergents. Dioxins are primarily the by-products of chemical process manufacturing and incineration of industrial and municipal wastes.

Many potential estrogenic chemicals persist in the environment and some, especially the organochlorine pesticides may bioconcentrate, bioaccumulate or biomagnify within the food web. These three processes result in a higher concentration of a chemical in living organisms than is present in the surrounding air, soil or water. Bioconcentration is the net accumulation of a chemical directly from water by an aquatic organism;

Table 1

Potential Environmental Estrogens

Organochlorine Pesticides	Other Organochlorines	Other Pesticides
2,4,5-T	*PCBs*	Parathion
Chlordane	*PBBs* [2]	Pyrethrins
Oxychlordane [1]	Dioxins	Trifluralin
trans-Nonachlor [1]		
DBCP	**Carbamate Pesticides** [3]	**Metals**
DDT, DDD, DDE	Benomyl	Cadmium
Dieldrin	Mancozeb [4]	Lead
Heptachlor	Maneb [4]	Mercury
Hexachlorobenzene	Metiram-complex [4]	Tributyl tin
Mirex	*Zineb* [4]	
Nitrofen	Ziram	**Other Industrial Chemicals**
Pentachlorophenol	Methomyl	Phthalates
Toxaphene	Carbaryl	Styrenes
2,4-D	Aldicarb	Pentyl- to nonyl-phenols
Alachlor		
Dicofol	**Triazine Herbicides**	**Synthetic Estrogens**
Endosulfan	Amitrole	Diethylstibestrol
Lindane (γ-HCH)	Atrazine	Ethinylestradiol
-Lindane (-HCH)	Metribuzin	
Methoxychlor		

References:Colborn, et al. 1993 and Hazardous Substances Database (HSDB) 1995.

Chemicals in italics are no longer manufactured or registered for use in the United States or their use has been greatly restricted.

The use of 2,4,5-T was canceled in 1985.

The use of chlordane was canceled in 1988.

The use of DBCP, except as a soil fumigant for pineapples, was canceled in 1981.

The use of DDT, except in public health emergencies, was canceled in 1972.

The use of dieldrin and aldrin, except as a termiticide, was canceled in 1974.

The use of heptachlor, except to control fire ants in power transformers, was canceled in 1983.

The use of hexachlorobenzene as a fungicide was canceled in 1985.

Notes for Table 1, continued

The use of mirex was canceled in 1977.

All products that contained Nitrofen were canceled in 1983.

As of 1989, pentachlorophenol was no longer available for over-the-counter purchase; some wood preservative uses are still allowed.

Most uses of toxaphene were canceled in 1982.

The EPA has canceled all dicofol products containing more than 0.1% DDT. Since 1986, the sale, distribution, and shipment of existing stocks of dicofol products containing more than 0.1% DDT has been prohibited.

The use of polychlorinated biphenyls (PCBs) was banned in 1979.

(1) Oxychlordane and trans-Nonachlor are metabolites of the organochlorine pesticide chlordane. These chemicals are often found in the blood of people and animals that have been exposed to chlordane. No commercial use of these compounds was reported (HSDB 1995).

(2) PBBs (polybrominated biphenyls) are chemically similar to PCBs but contain bromine substituents instead of the chlorine substituents found in PCBs. The use of PBBs has been banned.

(3) Carbamate or dithiocarbamate pesticide.

(4) Ethylenebisdithiocarbamate (EBDC) derivative.

All registrations for Zineb have been canceled.

In 1992, the EPA canceled the use of other EBDC products (mancozeb, maneb, and metiram) for 11 food uses while allowing its continued use on 45 other food crops. Home garden uses of mancozeb on turf and fruit were canceled.

bioaccumulation is the net accumulation of a chemical by an organism as a result of uptake from all routes of exposure, and biomagnification is the tendency of some chemicals to accumulate to higher concentrations at successive steps within the food web. Many, but not all, xenoestrogens are subject to these environmental processes.

Eventually, all potential estrogenic chemicals (with the exception of metals) are subject to degradation to simpler molecules. Identifying and understanding the degradation processes are necessary to evaluate the fate of potential environmental estrogens in the natural environment and during the primary, secondary and tertiary wastewater treatment processes at the Laguna Plant.

Degradation processes may be biological (biodegradation) or chemical. Typical chemical processes include oxidation (degradation by reaction with oxygen), hydrolysis (degradation by reaction with water often under acidic or alkaline conditions), and photolysis (degradation by reaction with light). Biodegradation may either occur aerobically (i.e., in the presence of oxygen) or anaerobically (i.e., in the absence of oxygen). Potential environmental estrogens go through multiple degradation steps as they are broken down to simpler molecules (e.g., carbon dioxide, methane, oxygen, water, chloride). The complete degradation of the organic chemicals to carbon dioxide and other simple molecules is called mineralization. The relative rate of a chemical's degradation is often expressed as a half-life, the length of time it takes for the chemical's concentration to decrease by 50%.

Potential environmental estrogens may also be removed from the aqueous environment by the processes of volatilization (loss to the atmosphere) and adsorption (adherence to soils and sediments). Volatilized or adsorbed chemicals may subsequently undergo degradation in the air or on the soil or sediment. Some small proportion of the chemicals may return to the water, but the net effect of these processes is a reduction of the concentration of the chemical in the water. The sources, current registration status (for pesticides) and environmental fate of specific chemicals are discussed in the following paragraphs.

Organochlorine Pesticides

About one-third of the chemicals listed in Table 1 are organochlorine pesticides or their metabolites. Because of their known adverse effects on human health and the environment the use of several of these pesticides, including 2,4,5-T, chlordane, dibromochloropropane (DBCP), dieldrin, DDT, heptachlor, hexachlorobenzene, β-lindane, mirex, nitrofen, pentachlorophenol, and toxaphene, has been canceled or greatly reduced in the United States since the 1970s (HSDB 1994, HSDB 1995, Soto et al. 1994). Others, such as the herbicides 2,4-D and alachlor and the insecticides dicofol, endosulfan, lindane, and methoxychlor are still in use.

2,4-D

2,4-D is a currently registered herbicide and a plant growth regulator. It will biodegrade in both soil (typical half-lives less than one day to several weeks) and water (typical half-lives 10 days to greater than 50 days). It will be more persistent in nutrient-poor/oxygen-rich waters and where high concentrations are released. Degradation will be rapid in sediments (half-life less than one day). Unlike many other organochlorine compounds, 2,4-D will not bioconcentrate in aquatic organisms and will not appreciably adsorb to sediments.

2,4,5-T

2,4,5-T was formerly used as an herbicide and plant growth regulator. Its use as an herbicide in the United States was canceled in 1985. In soil, 2,4,5-T is expected to biodegrade. It has been reported to persist in soil for between 14 to 300 days, but usually not more than one full growing season regardless of application rate. In water, photodegradation, volatilization and biodegradation of 2,4,5-T appear to be the dominant removal mechanisms. The aquatic, near surface half-life for photolysis has been calculated to be 15 days during the summer at latitude 40 degrees. Bioconcentration in aquatic organisms is not expected to be significant.

Alachlor

Alachlor (common trade name Lasso®) is a currently registered herbicide used to control annual grasses and many broadleaf weeds. In soil, alachlor is expected to biodegrade (half-life of about 15 days). Alachlor is highly to moderately mobile in soil. Mobility decreases with an increase in organic carbon and clay content in soil. In water,

hydrolysis, photodegradation and biodegradation are important for the loss of alachlor. The hydrolysis half-life is reportedly about 15 days, but the photodegradation half-life is reported to be shorter (Chiron et al. 1995). Bioconcentration in aquatic organisms is not significant. Alachlor has been widely detected in surface water and groundwater around farmlands.

Chlordane

Chlordane was formerly used as an insecticide. Oxychlordane and trans-nonachlor are metabolites of chlordane; these chemicals are often found in the blood of people and animals that have been exposed to chlordane. No commercial use of these compounds has been reported. Currently, there are no approved uses for chlordane in the United States. Its use was canceled in 1988. In soil, chlordane may persist for long periods of time. Under field conditions, the mean degradation rate has been observed to range from 4.05% to 28.33% per year with a mean half-life of 3.3 years. Chlordane is expected to be generally immobile or only slightly mobile, however, its detection in groundwater samples in New Jersey and elsewhere indicates that movement to groundwater (from soil application) can occur. Chlordane can volatilize significantly from soil surfaces on which it has been sprayed, particularly moist soil surfaces, however, shallow incorporation into soil will greatly restrict volatile losses. Chlordane appears to be very slowly biodegraded in the environment, which is consistent with the long persistence periods observed

under field conditions. In water, chlordane is not expected to undergo significant hydrolysis, oxidation or photodegradation. Adsorption to sediment is expected to be a major fate process based on soil adsorption data and extensive sediment monitoring data. Bioconcentration is expected to be significant.

DBCP

1,2-dibromo-3-chloropropane (DBCP) was formerly used as a nematicide (kills roundworms) and soil fumigant. Its use as a pesticide was canceled in 1981 but it is still used as a laboratory reactant. This use is not expected to result in significant releases to the environment. In soil, DBCP will volatilize or leach to groundwater. In alkaline soils, hydrolysis may be significant and biodegradation is possible but is expected to be slow relative to volatilization and leaching to groundwater. In water, DBCP is expected to volatilize rapidly and hydrolyze slowly (half-life of about 28 years at 25^{o} C). In groundwater, DBCP is expected to persist due to its low estimated rate of hydrolysis (half-life of about 141 years at 15^{o} C). Biodegradation may occur, but is expected to be slow relative to the rate of volatilization. Adsorption to sediments and bioconcentration are not expected to be significant.

DDT / DDD / DDE

DDT was formerly used in the United States to control many insects including those that carry malaria, typhus, plague, and yellow fever. It was released for commercial use on 31 August 1945 but has been banned since 1972. It adsorbs very strongly to soil and is subject to volatilization and photodegradation at the soil surface. It will not leach appreciably to groundwater or hydrolyze but may be subject to biodegradation in flooded

soils or under anaerobic conditions. In water, it will adsorb very strongly to sediments and be subject to volatilization and photodegradation near the surface. It will not hydrolyze and will not significantly biodegrade in most waters. Biodegradation may be significant in sediments. Two related compounds, DDD and DDE, are degradation and/or metabolic products of DDT. DDD and DDE may also occur as contaminants of DDT that arise during its manufacture. DDD and DDE have chemical and physical properties similar to DDT and are also resistant to degradation. Of these three compounds, DDE appears to be the most stable and resistant to biodegradation (Clement Associates 1989). Bioaccumulation and bioconcentration are significant for DDT, DDD and DDE.

Dicofol

Dicofol (common trade name Kelthane®) is a currently registered pesticide used primarily to control mites on fruits, vines, ornamentals, vegetables, and field crops. In soil, it is expected to be generally immobile or only slightly mobile. It has been detected in groundwater in some areas of the United States. It is susceptible to hydrolysis in moist soils and volatilization from the surface of moist soils. It is resistant to biodegradation. In water, dicofol is expected to bind to sediments and will be subject to hydrolysis and possibly photodegradation. It may bioconcentrate in aquatic organisms.

Dieldrin

Dieldrin was formerly used as an insecticide on corn and for termite control in buildings. Registration for general use in the United States was canceled in 1974. Dieldrin is extremely persistent, but is known to slowly photodegrade to photodieldrin (half-life in water of about four months) in the light. In soil, it will persist for long periods (more than seven years). Dieldrin is not expected to leach to groundwater but will reach surface water with surface runoff. Once dieldrin reaches surface waters it will adsorb strongly to sediments, bioconcentrate in fish and slowly photodegrade.

Endosulfan

Endosulfan (common trade name Thiodan®) is a currently registered insecticide used to control various insects and mites on cereals, coffee, cotton, fruit, oilseeds, potatoes, tea, vegetables, and numerous other

crops. Technical grade endosulfan is composed of α-endosulfan and β-endosulfan. In soil, endosulfans will most likely biodegrade and hydrolyze, especially under alkaline conditions. Endosulfans on the soil surface may photodegrade. Volatilization and leaching are not expected to be significant because endosulfan adsorbs strongly to soils. In water, endosulfans are expected to hydrolyze readily under alkaline conditions, and more slowly at neutral and acidic pH values (alpha half-lives are 35.4 and 150.6 days for pH 7 and 5.5, respectively; beta half-lives are 37.5 and 187.3 days for pH 7 and 5.5 respectively). Volatilization and biodegradation are also expected to be significant. Photodegradation and oxidation may also be important. Bioconcentration ofendosulfan is expected to be significant.

Heptachlor

Heptachlor was formerly used as a general pesticide to control flies, mosquitoes, fleas, and termites in buildings and as an insecticide on seeds, fruits, vegetables and cotton. Since 1983, the use of heptachlor in the United States has been restricted to the control of fire ants in power transformers. All other uses have been canceled. In soil, heptachlor volatilizes from the soil surface, especially in moist soils, but volatilization of heptachlor incorporated into soil is slower. It may also hydrolyze and biodegrade. Heptachlor is expected to adsorb strongly to soil and, therefore, to resist leaching to groundwater. In water, heptachlor will hydrolyze to 1-hydroxychlordene (half-life of about one day) and volatilize. Adsorption to sediments may occur. Biodegradation of heptachlor is expected to be slow compared to hydrolysis. Bioconcentration of heptachlor may be significant.

Hexachlorobenzene

Hexachlorobenzene is formed as a waste product in the production of several chlorinated hydrocarbons and is a contaminant in some pesticides. Its use as a fungicide in the United States was canceled in 1985 (Colborn and Clement 1992). It may enter the environment in air emissions and wastewater in connection with the manufacture of pesticides and in flue gases and fly ash from waste incineration. Hexachlorobenzene is a very persistent environmental chemical due to its chemical stability and resistance to biodegradation. In soil, hexachlorobenzene will be strongly adsorbed and therefore is not generally susceptible to leaching. In water, hexachlorobenzene will adsorb to sediment and suspended matter and it will volatilize. Hexachlorobenzene will bioconcentrate in fish and enter the food web (it has been detected in food during market basket surveys).

Lindane (- and -hexachlorocyclohexane)

Lindane [containing primarily γ-hexachlorocyclohexane (γ-HCH) as the active ingredient] is a currently registered insecticide that is used on hardwood logs and lumber, seeds, vegetables and fruits, woody ornamentals, hardwood forests, livestock and pets, and existing structures. It is also used as a scabicide (kills mites) and pediculicide (kills lice) on humans and animals. In soil, lindane will volatilize or leach slowly to groundwater. In water, lindane is not expected to volatilize significantly. Lindane released to acidic or neutral water is not expected to hydrolyze significantly, but in basic water, significant hydrolysis may occur (half-life of 95 hours at pH 9.3). It has been reported to photodegrade in water, but photodegradation is not considered to be a major environmental fate process. Transport to sediments is expected to be slow and result predominantly from diffusion rather than settling. Lindane will slowly biodegrade in aerobic media and will rapidly degrade under anaerobic conditions. Lindane will bioconcentrate slightly in fish.

β-hexachlorocyclohexane (β-HCH) is one of several isomers of HCH that are also commonly referred to as lindane (technical grade lindane has historically been a mixture of these isomers). β-HCH is no longer manufactured or used in the United States. Its

environmental fate is probably similar to that of γ-HCH, the active ingredient of commercial lindane formulations.

Methoxychlor

Methoxychlor is a currently registered insecticide used for home and garden applications, livestock and poultry, alfalfa, soybeans, forests (Dutch Elm disease), ornamental shrubs, deciduous fruits and nuts, and vegetables. In soil, methoxychlor is expected to remain immobilized primarily in the upper layer of soil although a small percentage may migrate to groundwater as suggested by the detection of methoxychlor in some groundwater samples. Under anaerobic conditions, biodegradation appears to be the dominant removal mechanism, however, under aerobic conditions, biodegradation is expected to be less rapid and possibly negligible. Rapid primary degradation of methoxychlor has been observed under anaerobic conditions in flooded soils (half-lives one week to less than two months). Methoxychlor may undergo photodegradation on the soil surfaces and chemical hydrolysis in moist soils (half-life greater than one year). In water, methoxychlor may adsorb to suspended solids and sediments or it may undergo photodegradation (half-life of less than five hours to about 4.5 months). Volatilization of methoxychlor may be significant (half-life of 4.5 days from a shallow river) and it may also biodegrade under anaerobic conditions (half-life of less than 28 days in sediments) or aerobic conditions (half-life of more than 100 days in sediments). Bioconcentration may occur in certain aquatic organisms, although fish are reported to metabolizemethoxychlor fairly rapidly.

Mirex

Mirex is a highly stable insecticide formerly used for fire ant control in the southeastern United States. Mirex was also employed as a flame-retardant. Mirex was banned in 1978. It is resistant to biological and chemical degradation. Photodegradation of mirex may occur. Mirex is expected to strongly adsorb to organic materials in soils and sediments. It is expected to be immobile in soil and to partition from water to sediments and suspended material. Mirex has been shown tobioconcentrate in aquatic organisms.

Nitrofen

Nitrofen was formerly used as an herbicide for control of annual grasses and broadleaf weeds on a variety of food and ornamental crops. Nitrofen has not been registered for use around homes and gardens. Its manufacture or sale in the United States was canceled in 1983. In soil, it will photodegrade on the soil surface and biodegrade below the soil surface. It adsorbs strongly to soil and leaching will be negligible. Biodegradation is fairly rapid in flooded soil (half-life of about 10 days at 30^{o} C), but slow in upland soil, with substantial residues lasting through two growing seasons in cooler areas. In water, nitrofen is expected to adsorb strongly to sediment and particulate matter, photodegrade near the surface (65% degradation in one week) and biodegrade (99% degradation in 50 days). Bioconcentration in aquatic organisms is expected to be significant.

Pentachlorophenol

About 90% of the production of pentachlorophenol is used to preserve wooden utility poles, cross arms, and fence posts. These uses may result in some environmental releases from the wood and during spills. In soil, pentachlorophenol biodegrades slowly and leaches into groundwater. In water, pentachlorophenol adsorbs to sediment, photodegrades (especially at higher pHs) and slowly biodegrades. Bioconcentration in fish will be moderate. Pentachlorophenol's use on wood is restricted and its non-wood use is undergoing special review by EPA.

Toxaphene

Toxaphene is a mixture of 175 or more components that has been used extensively as a pesticide on cotton and other crops. Most uses of toxaphene were canceled in 1982. Toxaphene is very persistent in the environment. In soil, it will persist for long periods (one to 14 years) and is not expected to leach to groundwater or to be removed significantly by runoff unless adsorbed to clay particles which are removed by runoff. Biodegradation may be enhanced by anaerobic conditions such as flooded soil. Volatilization from soils and surfaces will be a significant process for toxaphene. Toxaphene released in water will not

appreciably hydrolyze, photodegrade, or significantly biodegrade. It will strongly adsorb to sediments and bioconcentrate in aquatic organisms. An estimated half-life of approximately six hours for volatilization of toxaphene from a river one meter deep, flowing at 1 meter/second (m/sec) with a wind velocity of 3 m/sec indicates volatilization will be significant. Field studies have shown it to be detoxified rapidly in shallow bodies of water but only very slowly in deep bodies of water.

Status of Organochlorine Pesticides in Laguna Plant Wastewater

2,4,5-T, nitrofen, β-lindane, chlordane, dieldrin, DDT (and its metabolites DDD and DDE), heptachlor, hexachlorobenzene, mirex, pentachlorophenol, toxaphene, and dibromochloropropane (DBCP) have been banned or restricted by the EPA and therefore are unlikely to be present in concentrations significantly above background in either the influent or effluent at the Laguna Plant. Because chlordane has been banned, its two metabolites, oxychlordane and trans-nonachlor, are also unlikely to be present. Since 1991, ten of these chemicals, β-lindane, chlordane, dieldrin, DDT, DDD, DDE, heptachlor, hexachlorobenzene, pentachlorophenol, and toxaphene, have been on the list of analytes for the quarterly monitoring events at the Laguna Plant. In addition, 2,4,5-T, DBCP, and trans-nonachlor are on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project.

2,4-D, alachlor, γ-lindane, endosulfan, dicofol, and methoxychlor are currently registered for use and therefore could be present in wastewater influent at the Laguna Plant. Since 1991, three of these chemicals, γ-lindane, endosulfan, and methoxychlor, have been on the list of analytes for the quarterly monitoring events at the Laguna Plant. In addition,

2,4-D and alachlor are on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project.

Other Organochlorines

Three of the chemicals in Table 1 are organochlorine compounds, but are not pesticides. Polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs) are chemicals that have had a variety of industrial uses, but that are now banned in the United States. Dioxins are by-products of specific industrial processes (e.g., paper manufacturing) and waste incineration.

Polychlorinated and Polybrominated Biphenyls

PCBs and PBBs have had many industrial applications because of their stability, inertness, electrical insulation properties, miscibility with organic solvents and low solubility in water (International Labour Organization, 1989). PCBs have had wide use as coolants and lubricants. They commonly have been used in electrical transformers, capacitors, fluorescent light ballasts, and hydraulic, lubricating and cutting oils. PCBs also have been used for their waterproofing properties and for their ability to improve the effectiveness of pesticides. They have been used in paints, inks, waterproof coatings for textiles, wood, metal and concrete, carbonless copy paper, wrapping paper for citrus fruit, insecticides and bactericides. PBBs have been used in much smaller quantities than PCBs, chiefly as fire retardants and in plastic parts that are subject to heating, such as televisions, radios and hand tools (Harte, et al. 1991).

Commercial production of PCBs began in the United States in 1929 (M.S. Golub, et al., 1991). They were marketed under trade names such as Aroclor, Clophen, Kanechlor and Fenclor. It has been estimated that 454 million kilograms of PCBs had been sold in North America by 1970 (Deichmann 1981). In 1971, the sole United States producer, Monsanto Company, voluntarily agreed to limit the sale of PCBs to those applications that minimized their introduction into the environment. The manufacture of PCBs was banned in the United States in 1979. PBBs have also been banned. Although banned in the United States, both types of chemicals persist in the environment because old equipment and products that may

still contain PCBs are still in use and because the properties that made their industrial use desirable, stability and inertness, also cause them to persist in the environment.

Dioxins

There are 75 possible polychlorinated dibenzo-*p*-dioxins (dioxins) and 135 different polychlorinated dibenzofurans (dibenzofurans), a related class of compounds. Of these, only seven dioxins and ten dibenzofurans, those with chlorine atoms in the 2,3,7, and 8 positions, are thought to have "dioxin-like" toxicity. The most widely studied dioxin (and the one for which the most toxicity data have been collected) is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). Similar to other organochlorine compounds, dioxins have a low solubility in water, a high solubility in fat, and tend to bioaccumulate. They are byproducts of various combustion and chemical processes and have never been

intentionally produced other than on a laboratory-scale basis for use in chemical analyses (USEPA 1994). Dioxins can be found throughout the world in practically all media (air, soil, water, and sediments) and in many organisms (e.g., fish, shellfish, domestic livestock). They have been detected in meat and dairy products.

Most dioxins enter the environment via air emissions. Dioxins are byproducts of the production of chlorine, chlorinated compounds and bleached pulp and paper and they are produced during the incineration of wastes and the combustion of coal, wood, petroleum products and used tires for energy generation. The largest releases to water (less than 1% of the total emissions to all media in the United States) are from bleached-chemical pulp and paper mills. Historical data (from sediment samples) indicate that environmental dioxin concentrations began to increase in the 1920s. Concentrations continued to increase until about 1970 and have been declining since 1980. The decline can probably be attributed to changes in industrial and incineration technologies that have occurred in recent years as a result of the concern about the adverse health effects of dioxins and the awareness of operators of manufacturing facilities and incinerators of the possible sources of this chemical.

Status of Other Organochlorines in Laguna Plant Wastewater

Since 1991, several of the more common and water soluble PCBs have been on the list of analytes for the quarterly monitoring events at the Laguna Plant. PBBs have not been analyzed but are less likely to be present because they are generally less soluble and were used less extensively than PCBs. PCBs are on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project.

Since July 1994, several dioxins have been on the list of analytes for the quarterly monitoring events at the Laguna Plant. Dioxins are on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project.

Carbamate Pesticides

Nine of the chemicals in Table 1 are carbamate or dithiocarbamate pesticides. They have a variety of uses (or former uses) as fungicides, insecticides, molluscicides (kills mollusks, e.g., snails), acaricides (kills mites), and nematicides (kills roundworms). All, except Zineb, are currently registered for use in Calfornia.

Benomyl

Benomyl (common trade name Benlate®) is a currently registered fungicide and is effective against a wide range of fungi that affect field crops, fruits, nuts, ornamentals and turf. It is also used to control mites on fruits and vegetables, both pre- and post-harvest. In soil, hydrolysis of benomyl is probably the primary removal process although biodegradation may also be significant. Some volatilization may also occur. In water, benomyl has a low to moderate tendency to adsorb to sediments. Hydrolysis will probably be the most significant removal process for benomyl in water (half-life of less

than one week) although biodegradation and photodegradation may also be important. Bioconcentration is not expected to be significant.

Mancozeb

Mancozeb, a complex of maneb and zinc, is a currently registered fungicide used to control diseases (e.g., blight, leaf spot, rust, downy mildew, scab) in field crops, fruits, nuts, vegetables, and ornamentals. In soil, mancozeb will biodegrade with a half-life of approximately 70 days and it has a low mobility. In water, it hydrolyzes in about one day.

Maneb

Maneb is a currently registered fungicide used to control diseases on seeds, plants, fruits and vegetables. In both water or moist soil, maneb will degrade by hydrolysis, the rate of decomposition increasing with decreasing pH. Aeration increases the decomposition rate in water. Maneb has been shown to photodegrade and therefore, photodegradation may contribute to maneb's removal from sunlit water or surface soils. In general, hydrolysis and photodegradation are expected to be more important environmentally than biodegradation. The results of laboratory and field studies indicate that maneb is generally immobile in soil and leaching is not expected to be important.

Metiram

Metiram is a currently registered fungicide used on fruits, vegetables and grains. Metiram may decompose chemically in water and soil. Biodegradation of metiram in soil and water is also likely. Because of its low solubility, it is likely to adsorb to soil and suspended solids and sediments in water. Bioconcentration ofundecomposedmetiram in aquatic organisms may also be important.

Zineb

Zineb was formerly used as an agricultural fungicide (introduced in 1943) for fruits, vegetables, field crops, and ornamental plants. Prior to 1992, all registrations for zineb were voluntarily canceled by the manufacturers. It is no longer used in commercial products. Zineb residues in or on nearly all agricultural commodities (except grapes for wine designated for wine use) were prohibited after December 31, 1994. In soil, zineb will remain confined to the upper layer of soil and degrade with a half-life of 16 to 23 days. In water, zineb will adsorb to sediment and particulate matter and hydrolyze. Zineb does not appear to bioconcentrate in fish.

Ziram

Ziram (introduced in the 1930s) is a currently registered fungicide applied as a spray to fruits and vegetables and a vulcanization accelerator in the rubber-processing industry. Ziram is expected to adsorb moderately to the soil or sediment. No data were found on

its persistence in soil or natural waters. Littlebioconcentration is expected in aquatic organisms.

Methomyl

Methomyl is a currently registered insecticide used on vegetables and agricultural crops. In soil, methomyl biodegrades primarily to carbon dioxide (half-life of 14 days or less). A lag period of one to two weeks may occur in unacclimated soils (soils that have not been previously treated with methomyl) before biodegradation begins. A small degree of chemical hydrolysis may occur in moist soils. Methomyl

is probably susceptible to leaching. In water, methomyl will hydrolyze at half-life rates of about 54, 38 and 20 weeks at pH 6.0, 7.0 and 8.0, respectively, at 25° C. Decomposition occurs more rapidly on aeration, in sunlight or with increased alkalinity. Methomyl may be susceptible to significant biodegradation in natural water as it has been shown to be readily biodegraded in soil. Bioconcentration in aquatic organisms is not expected.

Carbaryl

Carbaryl (common trade name Sevin®) is a currently registered molluscicide, an insecticide and an acaricide used on a variety of crops, including cotton, fruits, vegetables and ornamental trees and shrubs. In soil, carbaryl will photodegrade at the soil surface at a rate dependent upon the soil water content (half-life of 97 hours in dry soil to 688 hours in wet soil). Carbaryl will hydrolyze relatively rapidly in moist alkaline soil, but only slowly in acidic soil. Carbaryl may leach to groundwater. In water, carbaryl will rapidly hydrolyze at pH 7 and above (half-life of 10.5 days, 1.8 days and 2.5 hours at pH 7, 8 and 9, respectively, 20° C). In acidic water, hydrolysis will be slow (half-life of 1,500 days at pH 5, 27° C). Photodegradation will be significant (half-life of 52 to 264 hours). At lower pH values, biodegradation may be significant. Adsorption to high organic content sediments has been demonstrated to be important. Bioconcentration is not expected to be significant.

Aldicarb

Aldicarb (common trade name Temik®) is a currently registered insecticide, acaricide and nematicide for soil use. It does not bind significantly to soil. Half-lives in soil have been reported to be seven days in loam soil under field conditions and a few days in greenhouse soil. A general range of persistence in soil of one to 15 days has been reported. Aldicarb may leach to the groundwater in some soils where the rates of hydrolysis and oxidation are relatively slow, as in the slow hydrolysis of aldicarb reported at pHs around 5.4. Aldicarb does not degrade in groundwater under aerobic conditions except at relatively high pH (pH 8.5). Reported half-lives in groundwater under anaerobic conditions at pH 7.7 to 8.3 were 62 to 1,300 days. In surface water, it will be subject to hydrolysis by both acid and base catalysis (half-lives of 131 days at pH 4 and 6 days at pH 9 at 20° C, but 3,240 days at pH 5.5 and 15° C). A half-life of five days was observed for lake and pond water. Aldicarb is not expected to adsorb to sediments or bioconcentrate in aquatic organisms.

Status of Carbamate Pesticides in Laguna Plant Wastewater

Except for zineb, all of the carbamate pesticides are currently registered for use and therefore could potentially be present in the Laguna Plant influent. However, as a group the carbamates readily biodegrade and hydrolyze in soil and water and it is likely that these chemicals would be significantly degraded by processes at the Laguna Plant. They do not persist in soil and water under most conditions for more than a few days to a few weeks and they do not bioconcentrate in aquatic organisms.

None of the carbamates is on the list of analytes for the quarterly montoring events at the Laguna Plant. Three of the chemicals, aldicarb (and its sulfur derivatives), methomyl and carbaryl are on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project. These three chemicals have the longest reported half-lives of the group and would therefore probably be the most likely to resist degradation during wastewater treatment.

Triazine Herbicides

Three of the chemicals in Table 1 are triazine herbicides. They have historically been used in large quantities on agronomic crops (e.g., corn) in the midwestern United States and are used in lesser quantities for weed control in landscape maintenance and forestry applications.

Amitrole

Amitrole is a currently registered herbicide used to control annual grasses, annual broadleaf weeds, perennial broadleaf weeds, and some aquatic weeds in marshes and drainage ditches. In soil, amitrole will degrade microbially and possibly chemically with an average persistence of 2 to 4 weeks. In water, amitrole is not expected to hydrolyze, photodegrade, or volatilize. An initial maximum half-life of 68 days was observed for amitrole applied to an outdoor pond with persistence exceeding 200 days. Bioconcentration in aquatic organisms is not expected to be significant.

Atrazine

Atrazine is a currently registered herbicide for control of broadleaf and grassy weeds. In the environment, chemical degradation is probably more important than biodegradation. Atrazine may hydrolyze fairly rapidly in either acidic or basic environments, yet is fairly resistant to hydrolysis at neutral pHs. The rate of hydrolysis increases upon small additions of humic materials (organic matter), indicating atrazine hydrolysis could be catalyzed. For example, the half-life of atrazine at 25^{o} C and pH 4 was 244 days without an additive and 1.73 days with the presence of 2% humic acid. At 25^{o} C, a 5 mg/l solution of fulvic acid (naturally occurs in soils and most surface waters) resulted in half-lives of 34.8, 174, 398 and 742 days at pHs of 2.9, 4.5, 6.0 and 7.0, respectively. Atrazine is expected to be highly to moderately mobile in soils and is not expected to strongly adsorb to sediments. Atrazine is not expected to bioconcentrate orvolatilize.

Metribuzin

Metribuzin is a currently registered herbicide used to control grasses and broadleaf weeds in agricultural crops. In soil, metribuzin is expected to biodegrade. The soil half-life is in the range of 14 to 60 days. Metribuzin is moderately adsorbed on soils with high clay and/or organic content. Little leaching occurs on soils with high organic content, but metribuzin is readily leached in sandy soils. In water, biodegradation may be important based on studies in soil. Slow hydrolysis may aid in metribuzin degradation. Bioconcentration in fish is not significant.

Status of Triazine Herbicides in Laguna Plant Wastewater

The triazine herbicides are currently registered for use (the manufacturer of amitrole has withdrawn the registration of this product for some uses) and therefore could potentially be present in the Laguna Plant influent. However, as a group the triazine herbicides readily biodegrade and hydrolyze in soil and water (in the presence of organic matter) and it is likely that these chemicals would be degraded by processes at the Laguna Plant. They do not persist in soil and water under most conditions for more than a few weeks, although under some conditions atrazine is more resistant to degradation. They do not bioconcentrate in aquatic organisms. Atrazine has the longest reported half-life of the group and would therefore be the most likely to resist degradation during wastewater treatment.

None of the triazine herbicides is on the list of analytes for the quarterly monitoring events at the Laguna Plant. Two of the chemicals, atrazine and metribuzin, are on the list of analytes for the reclaimed water quality study of theSubregional Wastewater Project.

Metals

Four of the chemicals in Table 1 are metals (cadmium, lead and mercury) or an organic complex of a metal (tributyl tin). The inorganic metals have a variety of industrial uses and potential environmental sources (including native soils) whereas tributyl tin has been introduced into the environment primarily from its use as an antifouling agent (inhibits attachment and growth of marine invertebrates) for marine vessels.

Cadmium

Pure cadmium is a naturally-occurring, silver-white, blue-tinged, lustrous metal. It may occur as cadmium salts, hydrated cations, or organic/inorganic cadmium complexes. Anthropogenic sources of cadmium include paints, batteries and plastics. Elemental cadmium is insoluble in water, while cadmium compounds have varying degrees of solubility depending on the nature of the compounds and the aquatic environment (ATSDR 1991). As hydrated cations or complexes, cadmium is fairly mobile in water (relative to other heavy metals). Cadmium in soils may leach into water, especially under acidic conditions. It does not volatilize from either waters or soils, but does exhibit a tendency to adsorb strongly to clays, muds, and humic/organic materials in soils and waters. Complexing and sorbing with organic materials are the most important

factors in aquatic fate and transport. Cadmium is expected to bioaccumulate in all levels of the food web.

Lead

Lead is a naturally-occurring element which is dispersed throughout the environment primarily as a result of human activities. Major sources of lead come from its former use in automobile fuels and lead-based paints. Along roadways and adjacent to houses with exterior lead-based paints concentrations may be as high as 10,000 ppm (ATSDR 1988). Lead is extremely persistent in both water and soil. Environmental fate processes may transform one lead compound to another; however, lead itself is not degraded. It is largely associated with suspended solids and sediments in aquatic systems, and it occurs in relatively immobile forms in soil. Lead bioaccumulates in animal tissues, but does not biomagnify in the food web.

Mercury

Mercury is a naturally-occurring, silver-white, heavy, mobile, liquid metal exhibiting slight volatility at room temperature. Anthropogenic sources of mercury in the environment include consumer products, such as thermometers, batteries, and electrical switches; agricultural chemicals; and antifouling paints. Mercury is also a byproduct of the ore smelting industry and the combustion of fossil fuels. Mercury may exist as one of three forms: elemental mercury, inorganic mercury, and organic mercury. Organic mercury compounds are more easily absorbed than elemental and/or inorganic forms, but will readily undergo biodegradation with the ultimate release of inorganic mercury. Organomercury compounds, especially alkyl mercury compounds, are viewed as posing the greatest toxicological danger. Given their high specific gravity/density values, elemental and inorganic mercury compounds are generally susceptible to gravitational deposition in sediments of aqueous environments. Mercury entering surface waters can be microbially converted to methylmercury given favorable conditions. The organic forms of mercury are subject to the greatest bioaccumulation.

Tributyl tin

Tributyl tin is a member of the family of organotins. Production of organotins has paralleled closely the growth of PVC plastics, especially rigid PVC for which dialkyltins generally are used. The use of organotins as stabilizers accounts for about 70% to 90% of the market and biocidal use (primarily as an anti-fouling agents for marine vessels) accounts for most of the remainder. Their biocidal use has been restricted by the EPA. Organotin compounds released into the environment are not stable. They degrade over a period of a few days to several weeks by photochemical and biochemical processes. They may also undergo biological methylation to mono-, di-, tri-, and tetramethyltin. In estuaries, the concentration of methyltin increases with salinity. The slow methylation of trimethyltin to water soluble, volatile tetramethyltin contributes to the flow of organotin to the atmosphere. Tin in every form can bioconcentrate in marine organisms and concentrations can reach a few mg/kg of body weight.

Status of Metals in Laguna Plant Wastewater

Since 1988, cadmium, lead, and mercury have been on the list of analytes for the periodic(monthly or quarterly) monitoring events at the Laguna Plant. All three are on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project.

Tributyl tin is not on the list of analytes for the quarterly monitoring events at the Laguna Plant and is not on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project. Because its biocidal use has been restricted and because tributyl tin degrades relatively quickly, there is a low probability that it will be present at biologically active concentrations in the Laguna Plant effluent.

Other Pesticides

Three of the chemicals in Table 1 are pesticides that do not fall into the previously described (organochlorine, carbamate, or triazine) pesticide categories. Two (parathion and pyrethrins) are insecticides and one (trifluralin) is an herbicide.

Parathion

Parathion is a currently registered insecticide used on a variety of agricultural crops. Parathion residue on foliage will decay with a half life of one day reaching low levels in a week or two. It will bind tightly to soil and decay by biological and chemical hydrolysis in several weeks. Photodegradation may occur on the soil surface. Degradation in flooded soil is much faster and is probably due to surface-catalyzed hydrolysis. Residues will generally remain in the upper 6 inches of soil so leaching into groundwater is unlikely. Parathion released into surface waters will be removed in approximately one week. The primary removal mechanism is adsorption to sediment and particulate matter where biodegradation or chemical hydrolysis will occur. While photodegradation in water occurs with a half-life of less than one to ten days, eutrophic waters (those enriched in nutrients) may greatly accelerate this process. Bioconcentration is expected to be low to moderate.

Pyrethrins

Pyrethrins are currently registered insecticides that cause rapid knockdown of treated insects. They are a natural insecticide produced by plants, and are used in animal sprays, household sprays, industrial sanitation sprays, and to protect stored food in warehouses. They are generally unstable in the presence of light, rapidly hydrolyzed by alkali and rapidly oxidize in air. Therefore, they are susceptible to oxidation in aerobic soil and hydrolysis in basic soil. In air, pyrethrins will degrade rapidly in the vapor phase by reaction with ozone and photochemically produced hydroxyl radicals (estimated half-life of 14 minutes). Particulate phase pyrethrins will be removed physically from air by wet and dry deposition. In soil or water, pyrethrins are expected to degrade rapidly through biodegradation, hydrolysis and photodegradation. The photodegradation half-life in sunlight (at the water's surface or as a thin-film on dry surfaces) can be as fast as one

hour or less. Aqueous hydrolysis is expected to become important only in alkaline media (pH 8 or above). Pyrethrins are expected to have low mobility in soil and to partition into sediment in aquatic systems.

Trifluralin

Trifluralin (common trade name Treflan®) is a currently registered herbicide used to control grasses and broadleaf weeds. In soil, trifluralin is expected to biodegrade under both aerobic and anaerobic conditions and to volatilize to the atmosphere. The persistence of trifluralin in soil has been estimated at approximately 6 months. Trifluralin strongly adsorbs to soil. In water, trifluralin is expected to biodegrade under both aerobic and anaerobic conditions and to photodegrade. It is expected to bioconcentrate in aquatic organisms and adsorb strongly to sediment and suspended organic matter.

Status of Other Pesticides in Laguna Plant Wastewater

Parathion is not on the list of analytes for the quarterly monitoring events at the Laguna Plant or for the reclaimed water quality study of the Subregional Wastewater Project. However, parathion readily biodegrades, hydrolyzes and photodegrades in soil and water and it is likely that it would be significantly degraded by processes at the Laguna Plant.

Pyrethrins are not on the list of analytes for the quarterly monitoring events at the Laguna Plant and are not on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project. Because pyrethrins readily biodegrade, hydrolyze and photodegrade in soil and water, if any pyrethrins are present in the Laguna Plant influent, they are likely to be significantly degraded by the treatment processes.

Trifluralin is not on the list of analytes for the quarterly monitoring events at the Laguna Plant. It is, however, on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project.

Other Industrial Chemicals

The three chemicals in this category in Table 1 have a variety of industrial uses and potential environmental sources. Alkylphenols are degradation productions of a group of surfactants found in many consumer products. Those alkylphenols with a five (pentylphenol) to nine (nonylphenol) carbon side chain are reported to be estrogenic. Phthalates are found in many soft plastic products and styrene can be found in many consumer products.

Alkylphenols

Alkylphenols are degradation products of alkylphenol polyethoxylates, which are widely used in paints, plastics, textiles, paper, and detergents (Talmadge 1994). They were first manufactured in the 1940s and are currently the second largest group of nonionic surfactants in commercial production (White, et al. 1994). In 1988, about 450 million pounds of alkylphenol polyethoxylates were sold in the United States (Talmadge 1994).

An estimated 60% of production is reported to be discharged in household and industrial wastewater (Naylor, et al. 1992). During the treatment of wastewater, alkylphenol polyethoxylates are converted to both hydrophobic (non-soluble) and soluble degradation products. The degradation products are relatively stable and can adsorb to sediment and sludge (in the case of hydrophobic products) or to a lesser degree dissolve in surface and groundwater. It is reported that normal secondary wastewater treatment effectively removes more than 95% of the more common alkylphenolic compounds.

Some of the hydrophobic products (i.e., the pentyl- to nonyl-phenols) of alkylphenol polyethoxylates have been shown to be estrogenic. Concentrations of the alkylphenols in English rivers (where the estrogenic effects of these compounds have been studied most closely) reportedly range from 1 to 50 µg/L but may be as high as 1 mg/L for poor quality streams--especially downstream from textile mills (Raloff 1994). Concentrations in United States' rivers are reported to be less than 1 µg/L (Talmadge 1994).

Phthalates

Phthalates (more correctly phthalate esters) comprise various different esters of phthalic acid. They are used primarily as plasticizers for polyvinyl and cellulosic resins, primarily in polyvinyl chloride (PVC). The major use of butyl benzyl phthalate (BBP), for example, is in flooring materials with minor amounts used in household products. Bis-(2-ethylhexyl) phthalate (DEHP) is also used as a plasticizer and in addition is found in insect repellents, cosmetics, rubbing alcohol, liquid soap, detergents, decorative inks, lacquers, munitions, industrial and lubricating oils, and defoaming agents during paper and paperboard

manufacture. Di-N-butyl phthalate, DEHP and BBP have been detected in sewage sludges at various locations in the United States.

The environmental fate of the various different phthalate esters is similar. In water, the primary fate appears to be biodegradation (half-life of several weeks) but some adsorption to sediments will also occur. Volatilization and hydrolysis generally are not significant aquatic processes. In soil, phthalate esters are not expected to volatilize nor leach into groundwater significantly. Biodegradation is again the primary fate. BBP, for example, is readily biodegraded in activated sludge, semicontinuous activated sludge, salt water, lake water, and under anaerobic conditions. At an initial concentration of 1 mg/L in lake water, primary degradation accounted for more than 95% loss of BBP in seven days; after 28 days, 51 to 65% of BBP had mineralized. As a class, phthalates have a low potential to bioconcentrate (DEHP appears to possess the highest potential of those compounds for which information was available).

Styrene

Styrene is a petrochemical used in the production of plastics found in many consumer dry goods (e.g., automobile tires, PVC pipe, adhesives, copy paper and toner, inks, styrofoam cups, and combs) and chemicals (e.g., floor waxes and polishes, paints, metal cleaners, and varnishes). Styrene is also found in unsaturated polyester resin products used in fiberglass boat construction and repair, and as auto body fillers and casting plastics.

Significant amounts of styrene may be released to the environment from emissions generated by its production (which occurs primarily in Texas and Louisiana) and use, and from automobile exhaust (Harte, et al. 1991). In air, styrene reacts rapidly with both hydroxyl radicals and ozone with a combined, calculated half-life of about 2.5 hours. In water, styrene will volatilize relatively rapidly and may be subject to biodegradation, but is not expected to hydrolyze. In soil, it will biodegrade and leach with a low-to-moderate soil mobility. Styrene has been detected in various chemical, textile, latex, oil refinery and industrial wastewater effluents. The volatilization half-life of styrene from a well-mixed pool of water 1 meter deep is estimated to be approximately six hours. Styrene is not expected to bioaccumulate or bioconcentrate in organisms or biomagnify in the food web to any measurable extent.

Status of Other Industrial Chemicals in Laguna Plant Wastewater

Alkylphenols are not on the list of analytes for the quarterly monitoring events at the Laguna Plant. Although these chemicals are not part of the standard suite of chemicals that can be analyzed by commercial analytical laboratories, an attempt to analyze for them is being made for the reclaimed water quality study of the Subregional Wastewater Project.

Since 1991, BBP, DEHP, di-N-butyl phthalate, diethyl phthalate, dimethyl phthalate, and dioctyl phthalate have been on the list of analytes for the quarterly monitoring events at the Laguna Plant. All of these phthalates, except dioctyl phthalate, are on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project.

Since 1991, styrene has been on the list of analytes for the quarterly monitoring events at the Laguna Plant. It is also on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project.

Synthetic and Natural Estrogens

Two of the chemicals in Table 1 are synthetic estrogens that have been used for medical applications. This section also discusses the natural estrogens, which are synthesized and excreted by humans, farm animals and wildlife.

Diethylstilbestrol

Diethylstilbestrol (DES) is a synthetic estrogen that was first synthesized in 1938. From the late 1940s until 1971, an estimated 2 to 3 million women were prescribed DES during pregnancy to prevent spontaneous abortion and to reduce toxemia (blood poisoning), premature birth and stillbirth. About 1 to 1.5 million female and an approximately equal number of male offspring of these women are reported to have been exposed to the drug *in utero* (Steinberger and Lloyd 1985). DES has also been used as a feed supplement for cattle, sheep, and poultry (Knight 1980). Its use as a feed supplement for poultry was withdrawn by the Food and Drug Administration (FDA) in 1966. The use of DES as a drug during pregnancy was banned in 1971, although it may still be prescribed for treatment of certain menopausal symptoms and breast cancer (Steinberger and Lloyd

1985). Aqueous solutions of DES have been reported to lose their estrogenic activity rapidly (Knight 1980). Studies of the environmental fate of DES in soils are limited. One study reported that DES declined below detection limits (1 μg/kg) within six months for soils treated with the manure of steers fed DES. In a short term study (33 days) using a model ecosystem, measurable free DES persisted for the duration of the study and some bioconcentration of the chemical was reported.

Ethinylestradiol and Natural Estrogens

Ethinylestradiol is a synthetic estrogen that was first developed in 1938 (Guengerich 1990 and references therein). It is the major estrogenic component of the oral contraceptives (combinations of estrogen and progesterone analogs) commonly used for human birth control. Natural estrogens (e.g., estradiol-17β, estrone and estriol) are produced by humans and all species, sexes and classes of farm animals and wildlife. Humans and animals excrete the natural hormones (and some proportion of any synthetic hormones that they have ingested) in their urine and feces. In their excreted form the hormones are generally bound to a sugar molecule, which increases their water solubility. About 80% to 90% of the excreted estrogens are in urine. Human females excrete about 15 to 20 μg of estrogens (estrone, estradiol-17β and estriol) per day during the midfollicular phase of the menstrual cycle (Adlercreutz et al. 1994 and Goldin et al. 1982). Adult cows excrete about 30 mg of estrogens per day, cycling heifers excrete about 2.2 mg estrogens per day and hens excrete about 1.6 mg of estradiol per gram of dry excreta per day (Knight 1980 and references therein). Natural estrogens are reportedly stable in aqueous solution, a 1 mg/mL solution of estrone retaining 94% of its estrogenic activity after 27 weeks of storage at room temperature. Although certain bacterial species have been reported to degrade estrone, no reports were found on the stability ofethyinylestradiol,estradiol-17β, estrone and estriol in soil or fecal matter.

Status of Natural and Synthetic Estrogens in Laguna Plant Wastewater

DES is not on the list of analytes for the quarterly monitoring events at the Laguna Plant and is not on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project. Because the widespread use of DES has been canceled and because it is reported to lose its activity in water, there is a very low probability that biologically active concentrations of DES would be present in the Laguna Plant effluent.

Ethinylestradiol and natural estrogens are not on the list of analytes for the quarterly monitoring events at the Laguna Plant and are not on the list of analytes for the reclaimed water quality study of the Subregional Wastewater Project.

Summary of Potential Environmental Estrogen Status

The use of 19 of the chemicals or chemical groups that are identified in Table 1 as potential environmental estrogens was banned or restricted by the late 1980s. Most of these 19 chemicals are organochlorine compounds that persist in soil and water and bioaccumulate and biomagnify in the food web. Residues oftheir former use can still be

detected in soil and water samples and in tissue samples from animals (including humans, see Section 3). Because they have been banned or restricted, it is unlikely that these chemicals would enter the Laguna Plant's wastewater stream on a continuing basis above the ambient background soil and water concentrations. Nevertheless, 12 of the chemicals or groups of chemicals are on the list of analytes for the quarterly monitoring events at the Laguna Plant or for the reclaimed water quality study of the Subregional Wastewater Project (Table 2). The results of these analyses will be presented in the Reclaimed Water Quality Technical Report and will be used in a screening human health and ecological risk assessment.

The remaining 28 chemicals or chemical groups in Tables 1 and 2 comprise a diverse group of pesticides, metals, industrial chemicals and synthetic estrogens. Eighteen of the chemicals or groups of chemicals are on the list of analytes for the quarterly monitoring events at the Laguna Plant or for the reclaimed water quality study of the Subregional Wastewater Project. The results of these analyses will be presented in the Reclaimed Water Quality Technical Report and will be used in a screening human health and ecological risk assessment.

Nine pesticides and the synthetic and natural estrogens are not on the list of analytes for the reclaimed water quality report or the quarterly water monitoring program. Most of the pesticides have a low probability of occurring in detectable concentrations in reclaimed water from the Laguna Plant because of their low usage in Sonoma County (Table 3). One of the ten pesticides (i.e., metiram-complex) has had no reported commercial or agricultural usage during 1992 and 1993 (the two most recently available years) and is not registered for home use (State of California 1994, 1995). Five of the pesticides, parathion, pyrethrins, maneb, amitrole, and ziram, have had very low commercial or agricultural usage (from less than one pound up to 350 pounds per year for

Table 2

Status of Potential Environmental Estrogens

Organochlorine Pesticides		Other Organochlorines		Other Pesticides	
2,4,5-T	A,B	PCBs	A,B	Parathion	
Chlordane	A,B	PBBs	B	Pyrethrins	
Oxychlordane	B	Dioxins	A	Trifluralin	A
trans-Nonachlor	A,B				
DBCP	A,B	**Carbamate Pesticides**		**Metals**	
DDT, DDD, DDE	A,B	Benomyl		Cadmium	A
Dieldrin	A,B	Mancozeb		Lead	A
Heptachlor	A,B	Maneb		Mercury	A
Hexachlorobenzene	A,B	Metiram-complex		Tributyl tin	B
Mirex	B	Zineb	B		
Nitrofen	B	Ziram		**Other Industrial Chemicals**	
Pentachlorophenol	A,B	Methomyl	A	Phthalates	A
Toxaphene	A,B	Carbaryl	A	Styrenes	A
2,4-D	A	Aldicarb	A	Pentyl- to nonyl-phenols	A
Alachlor	A				
Dicofol		**Triazine Herbicides**		**Synthetic Estrogens**	
Endosulfan	A	Amitrole		Diethylstibestrol	B
Lindane (γ-HCH)	A	Atrazine	A	Ethinylestradiol	
β-Lindane (β-HCH)	A,B	Metribuzin	A		
Methoxychlor	A				

A - Chemical has been analyzed as part of the Laguna Plant's quarterly water monitoring program or is being analyzed as part of the water quality studies for The Subregional Wastewater Project.
B - Use of chemical has been banned or restricted in the United States.

Table 3

Fate and Usage of Pesticides

Chemical	Half-life in Water	Half-life in Soil	Pounds Applied in 1992[1]	Pounds Applied in 1993[2]	Home Use[3]
Organochlorine Pesticides					
Dicofol	N.A.	N.A.	4,300	1,400	No
Carbamate Pesticides					
Benomyl	< 7 days	N.A.	1,700	1,800	Yes
Mancozeb	1 day	70 days	8,700	28,000	No
Maneb	N.A.[4]	N.A.[4]	2.9	16	No
Metiram-complex	N.A.	N.A.	0	0	No
Ziram	N.A.	N.A.	240	350	No
Triazine Herbicides					
Amitrole	68 days	14 to 28 days	3.6	< 1	No
Other Pesticides					
Parathion	1 to 10 days	1 day[5]	1.9	10	No
Pyrethrins	< 1 day	< 1 day	93	34	Yes

N.A. - Not Available

(1) State of California, Department of Pesticide Regulation, Annual Pesticide Use Report for Sonoma County, January to December 1992, 12 February 1994.

(2) State of California, Department of Pesticide Regulation, Annual Pesticide Use Report for Sonoma County, January to December 1993, 1 March 1995.

(3) State of California, Department of Pesticide Regulation, Pesticide Registration Branch, 11 August 1995.

(4) Maneb and mancozeb are chemically related; mancozeb is a complex of maneb and zinc. Although no half-lives were reported for maneb in water and soil they are probably similar those for mancozeb.

(5) Half-life on plant foliage.

all of Sonoma County). Pyrethrins are registered for home use and the actual usage would be higher than that reported in Table 3. However, they have an extremely short half-life (less than one day). It is therefore unlikely that these six pesticides would occur in detectable concentrations in the Laguna Plant influent or effluent.

The remaining three pesticides, dicofol, benomyl, and mancozeb, had reported commercial or agriculture usage of more than 1,000 pounds per year in 1992 and 1993 in Sonoma County. Benomyl is registered for home use and actual usage would be higher than that reported in Table 3. However, both benomyl and mancozeb have relatively short half-lives, about seven days and one day, respectively, indicating that they would be significantly degraded and their concentrations reduced by the wastewater treatment process. The half-life of dicofol was not reported. Because of the high usage of benomyl and mancozeb and the unknown half-life of dicofol, it is not possible to exclude the possibility that these chemicals may occur in detectable concentrations in the Laguna Plant influent or effluent.

Among the synthetic estrogens, most uses of DES have been banned and it is unlikely that DES would occur in detectable concentrations in the Laguna Plant influent or effluent. Ethinylestradiol is currently used for a variety of medical reasons and both ethinylestradiol and natural estrogens may be present in the Laguna Plant influent in their water soluble forms. They would be expected to be at least partially degraded by the treatment process. For example, the sugar molecule that increases their water solubility would be susceptible to cleavage. The loss of the sugar would render the biologically active sterol portion less water soluble, reducing the chemicals' potential concentrations in water. However, because of the unknown quantity of chemicals entering the system and unknown degree of degradation it is not possible to exclude the possibility that these chemicals may occur in detectable concentrations in the Laguna Plant influent or effluent.

3 HUMAN HEALTH EFFECTS OF ENVIRONMENTAL ESTROGENS

The postulated human health effects of environmental estrogens are based primarily on four types of studies including:

- epidemiological evidence from human studies that shows a positive correlation between the concentration of environmental estrogens in human tissues or the environment and an increase in specific human diseases and disorders, such as breast or testicular cancer and decreased sperm counts;
- epidemiological evidence from human studies of estrogenic drugs (e.g., diethylstilbestrol);
- evidence from animal studies of environmental estrogens and extrapolation of results to humans;
- evidence from studies of human cell cultures that are exposed to environmental estrogens.

A large (and ever growing) number of papers have been written on this topic and it is not possible to comprehensively and completely discuss all of the papers that have been written to date. Therefore, the following sections emphasize some of the most recent papers that have been written on this topic. Particular attention is given to those studies that correlate chemical body burden or dose information with observed, adverse health outcomes.

DEVELOPMENTAL AND REPRODUCTIVE EFFECTS

Evidence from Animal Studies

The estrogenic effects of the organochlorine pesticides are probably the best characterized of the chemicals listed in Table 1. The United States Public Health Service's toxicological profile for DDT, DDE and DDD presents evidence that DDT is estrogenic to rats when administered orally (Clement 1989 and references therein). This estrogenic activity was exhibited as an increase in uterine wet weight and increases in concentrations of RNA or DNA and/or carbohydrates in uterine tissue. Doses ranging from 50 to 100 mg DDT/kg body weight/day were reported to elicit estrogenic activity. (For comparison, liver tumors have been observed in rats maintained on diets containing 6.25 and 25 mg DDT/kg body weight/day.) The document notes, however, that there is no indication that DDT has an adverse effect on human reproduction. It also notes that no quantitative data are available to correlate environmental levels of DDT, DDE, and DDD with health effects although volunteers who consumed 0.61 mg/kg of body weight of DDT per day for an extended period of time, showed no adverse effects despite extensive testing to determine such effects.

The reproductive toxicity of PCBs to animals is well documented. The Department of Health and Human Services (DHHS) toxicological profile for PCBs notes that adverse reproductive effects have been observed in several species, including rats (decreased fertility in males, prolonged estrus), mice (decreased conception), monkeys (prolonged menstruation, decreased fertility), and mink (partial or total reproductive inhibition) (Clement 1993). Monkeys and mink are reported to be particularly sensitive, with effects occurring at doses in the range of 0.1 to 1 mg/kg body weight/day in intermediate duration studies. The DHHS document states that conclusive evidence for reproductive effects in animals indicates that PCBs are a potential reproductive toxicant in humans.

It has been reported recently that effluent from some sewage treatment plants in England is estrogenic to fish placed in the effluent (Jobling and Sumpter 1993; Purdom, et al. 1994). Alkylphenolic detergents have been implicated as the source of this estrogenicity because of their widespread use in England and because there have been previous reports of their estrogenicity (Jobling and Sumpter 1993 and references

therein). A more complete discussion of this work is contained in Section 4 of this technical report. Measurable quantities of the soluble degradation products of these detergents have been detected in groundwater and surface water in the United States and other countries (Clark et al. 1992, Talmadge 1994).

Evidence from Human Epidemiological Studies

A comprehensive analysis of historical data on male reproductive characteristics (i.e., sperm densities and seminal volumes) has concluded that there has been a general decline in semen quality over the past 50 years (Carlsen et al. 1992 and references therein). The study gathered data from 61 papers published between 1938 and 1990. Linear regression analysis of the sperm densities reported in those papers indicated that sperm densities had "declined appreciably" between 1938 and 1990, although the authors noted that it could not be determined whether or not the decline was continuing. The authors also have noted a concomitant increase in the incidence of testicular cancer and other adverse male reproductive health effects during the study time period (Giwercman et al. 1993). Carlsen et al. proposed that these changes were probably due to environmental rather than genetic factors although whether or not they could be attributed to environmental estrogens remains to be determined. Other factors have been identified that could affect male reproductive health, including infections, malnutrition, radiation, and stress (Michal et al. 1993). In addition, the major conclusion of the Carlsen study, that sperm densities have declined over the past 50 years, has been controversial and has been both disputed as a statistical artifact (Bromwich et al. 1994) and supported by subsequent work (Auger et al. 1995). In any case, none of these studies correlates body chemical burdens with adverse health outcomes. The direct evidence for adverse reproductive outcomes has come from specific exposures to chemicals in the workplace or pharmaceuticals by the general public.

Several documented cases of human exposures to pesticides (e.g., DBCP and chlordecone) and PCBs in the work place or drugs (e.g., DES) during "therapeutic" use have provided information about the potential adverse developmental or reproductive

health effects of environmental estrogens. The adverse reproductive effects of these chemicals were observed when workers were accidentally exposed to these chemicals or when a "therapeutic" dosage was administered for an extended period of time. While these chemicals would not be expected to occur in the Laguna Plant's effluent, they illustrate the types of adverse health effects that may be experienced from exposures to environmental estrogens at biologically active concentrations.

PCBs

Studies of the reproductive effects of PCBs on humans have been equivocal. One study of men who were occupationally exposed to PCBs showed no fertility abnormalities while other studies of men with low sperm counts found elevated levels of PCBs in the blood and an association between concentrations of certain specific PCBs in semen and decreased sperm motility (Clement 1993 and references therein). Due to confounding factors, including exposure to DDT and other organochlorine pesticides, any possible effects on sperm could not be attributed specifically to PCB exposure.

DBCP

In 1977, several cases of infertility were reported among men working in a California pesticide factory that produced the nematicide DBCP (Whorton 1977). The primary symptoms of exposure were reduced sperm counts and sperm motility. These men also had altered hormone levels (follicle stimulating hormone and luteinising hormone were elevated) as compared to a group of workers from the same factory with normal sperm counts and motility. Exposure levels were not determined by the study although length of exposure (as measured by the amount of time worked at the plant) was positively correlated with infertility. The minimum time of exposure for an affected worker was one year.

Chlordecone

Chlordecone was developed by Allied Chemical Corporation in the early 1950s and registered as a pesticide in 1955. Almost all of its commercial production in the United States occurred in Hopewell, Virginia. About 99% or the world's production was exported to Germany. In the United States it was used for formulating pesticide mixtures for ant and roach traps. Men who worked at the Hopewell plant in the mid-1970s were observed to have decreased sperm counts, reduced sperm motility and abnormal sperm morphology (Taylor et al. 1978 and Cannon 1978). Of 148 workers, 76 individuals experienced tremors as a result of exposure to chlordecone. Exposure levels were probably very high given that only minimal protective efforts had been enforced to avoid worker exposure to chlordecone (workers were reportedly covered with a fine white dust, rarely wore dust masks, were not given protective clothing and boots and frequently ate lunch in the production area). Virtually all workers at the plant had detectable levels of chlordecone in their blood. In those who had symptoms of chlordecone intoxication, the mean concentration was 2.53 μg/mL of blood whereas asymptomatic employees had a mean concentration of 0.60 μg/mL. Thirteen individuals reportedly had abnormal sperm counts and sperm motility. These symptoms were not correlated to exposure levels or blood concentrations.

DES

Two to three million pregnant women were prescribed DES from the 1940s through the 1960s. As a consequence of *in utero* exposure to DES, the daughters of these women have an increased incidence of clear cell adenocarcinoma of the vagina, as well as gross structural abnormalities of the cervix, uterus and fallopian tubes. The daughters are also more likely to have an adverse pregnancy outcome, including spontaneous abortions, ectopic pregnancies and premature delivery (Gray 1992). A standard DES daily dose schedule started with 5 mg in the sixth week of gestation and gradually increased to 150 mg by the thirty-sixth week (Herbst 1981). Among identified DES daughters (those women with reported abnormalities) the highest daily DES dosages ingested by the mother varied from 1 mg to 300 mg, and the total dosages of DES ingested throughout pregnancy ranged from 131 mg to 21,400 mg. Adverse effects on male offspring have also been observed, including chryptorchidism (undescended testes), incomplete or defective development of the testes, cysts in the epididymal ducts, and abnormalities such as low sperm counts, decreased sperm motility, and malformed sperm (Fink 1978). Because the adverse health effects of DES were delayed to the offspring of exposed individuals, some researchers have expressed concern that other potential environmental estrogens may act similarly (Colborn and Clement 1992).

CARCINOGENIC EFFECTS

Evidence from Human Epidemiological Studies

Several organochlorine pesticides and PCBs have been classified as known animal carcinogens by the EPA. However, the evidence for a link between these chemicals and human cancers, such as breast cancer, is equivocal. Other factors that may affect breast cancer rates are women's reproductive, menstrual and family histories. In a study that compared levels of chemical residues in breast fat of women with malignant and nonmalignant breast disease, elevated levels of PCBs, DDT and DDE were found in the fat samples collected from women with cancer, compared with those who had benign breast disease (Falck et al. 1992). However, the authors of this paper cited a contradictory study that showed no difference in the levels of DDE and PCBs between cases and controls. Both studies were conducted on relatively small samples (less than 40 women in each study, including both case and control groups).

A 1993 study examined DDE and PCB concentrations in the blood serum of 14,290 New York City women (Wolff et al. 1993). Data for the study were collected between 1985 and 1991. The study matched 58 of these women, who had a diagnosis of breast cancer one to six months after they entered the study, with 171 women from the same study population who did not develop cancer. Mean levels of DDE and

PCBs were higher for breast cancer case subjects than for control subjects, but paired differences were statistically significant only for DDE. The mean serum concentration of DDE was 11.0 $\pm$ 9.0 nanogram/milliliter of blood (ng/mL) for case subjects as compared to 7.7 $\pm$ 6.8 ng/mL for control subjects. Overall, there was about a fourfold increase in relative risk of breast cancer for an elevation of serum DDE concentrations from 2.0 ng/mL (10th percentile) to 19.1 ng/mL (90th percentile).

The author of the New York City study subsequently collaborated with researchers at the Kaiser Research Foundation in Oakland, California in a study of 57,040 San Francisco Bay Area women (Krieger et al. 1994). Out of this group, the researchers matched 150 case subjects (women who had been diagnosed with breast cancer) with 150 control subjects and then determined the DDE and PCB concentrations in their blood serum from blood samples that had been collected between 1964 and 1971. The blood samples had been collected and stored as part of a multiphasic health examination conducted in the late 1960s. Matched analyses found no differences in the case subjects' and control subjects' blood serum levels of DDE or PCBs. The authors concluded that the results did not support the hypothesis that DDE and PCBs are a risk factor for breast cancer. The authors noted that the average blood serum DDE concentrations (43.3 $\pm$ 25.9 ng/mL for case subjects and 43.1 $\pm$ 23.7 ng/mL for controls) in this study, in which samples were collected before the ban on DDT in 1972, were higher than those collected in the New York City study, in which samples were collected about 20 years after the ban.

Evidence from Cell Culture Studies

When human breast cancer cells are placed in an artificial culture medium containing human blood serum their proliferation is inhibited. Adding human estrogen (estradiol-17β or "E_2") to the culture relieves the inhibition and causes the cells proliferate. This estrogen-dependent growth has been used to develop a bioassay, the "E-screen," for the screening of various chemicals that are suspected of being estrogenic (Soto et al. 1992). Xenoestrogens can be added to the medium, and their effect on cell proliferation compared to human estrogen.

The lowest concentrations of E_2 that produced the maximal number of cells in the E-screen were 30 to 100 X 10^{-12} moles/L (about 8.1 to 27.2 ng/L) (Soto et al. 1992). DES produced a maximal number of cells similar to E_2 but at one-third to one-tenth the concentration (10 X 10^{-12} moles/L or about 2.7 ng/L). DDT and several alkylphenols were reported to induce maximal cell yields similar to E_2 but at higher concentrations [DDT at 30 X 10^{-6} moles/L (10.6 mg/L); pentylphenol at 10 X 10^{-6} moles/L (1.6 mg/L); nonylphenol at 10 X 10^{-6} moles/L (2.2 mg/L)]. Several fungal toxins, a plant-derived estrogen, and chlordecone also gave positive proliferative responses. Heptachlor, Arochlor 1221 (a PCB), chlordane, and mirex had no estrogenic activity in this bioassay.

In more recent research using the E-screen bioassay, endosulfan, dieldrin and toxaphene have been reported to induce cell proliferation (Soto et al. 1994). This paper reports the chemical concentrations at which the estrogenic effect was detected rather than the lowest concentrations needed for maximal cell growth reported in the earlier paper by Soto, et al. For comparison, the DDT concentration at which the estrogenic effect was detected is 10 X 10^{-6} moles/L (3.5 mg/L), slightly lower than the previously reported value, 30 X 10^{6}

moles/L (10.6 mg/L), for maximal cell growth. Endosulfan, dieldrin and toxaphene induced a response similar to DDT at 10 X 10^{-6} moles/L (about 4.1 mg/L, 3.8 mg/L, and 4.1 mg/L, respectively). Higher concentrations of dieldrin and toxaphene were toxic to the cells. The authors conclude that all three chemicals have estrogenic potency, albeit at concentrations six orders of magnitude higher (on a molar basis) than E_2.

Soto, et al. state that environmental estrogens may act cumulatively. Ten chemicals were tested both individually (at concentrations below their effective threshold) and in a mixture containing all ten compounds. The mixture induced a proliferative response although none of the chemicals individually

induced a response that was significantly different from the control. It is difficult to draw conclusions from this sort of test because there are many potential interactions (i.e., synergistic, antagonistic) between chemicals in such a complex mixture. The authors conclude that measuring the total estrogenic burden due to environmental contaminants may be more meaningful than assessing exposure by measuring the levels of each of the known environmental estrogens.

4 WILDLIFE EFFECTS OF ENVIRONMENTAL ESTROGENS

The authors of two recent reviews of the scientific literature propose that the effects of xenoestrogens on wildlife, in both terrestrial and aquatic species, are global in nature (Colborn and Clement 1992; Schmidt 1994). Populations of species within vast ecosystems, for example the Arctic and the Great Lakes (Ramsey 1993; Leatherland 1992; Fox 1992), as well as restricted or localized populations of species, near point-source pollution (Davis and Bortone 1992; Guillette et al. 1993), are reported to show the effects of xenoestrogens in abnormal expressions of morphology, physiology, sexual reproduction or behavior. Scientific reports demonstrate that through the process of bioaccumulation wildlife in the upper portion of the food web can be exposed to higher than ambient concentrations of some xenoestrogens by consuming xenoestrogen-containing organisms from the lower portion of the food web (Bowerman et al. 1993).

The best understanding of the cause and effect relationship between xenoestrogens and abnormalities in the behavior and biological processes of wildlife has come from animal studies involving high levels of exposure to estrogenic chemicals in laboratory experiments or in environments heavily contaminated by a single source of pollution, such as a spill or industrial waste discharge (Colborn and Clement 1992; Stone 1994). There appears to be little doubt that high concentrations of xenoestrogens can alter the normal development of certain animal species but the cause and effect relationship between low environmental concentrations of xenoestrogens and specific abnormalities in wildlife is not yet conclusively demonstrated in the scientific literature (Colborn and Clement 1992; Stone 1994). Anecdotal evidence suggests that the reproductive success of some wildlife species has declined as environmental concentrations (including body burdens) of xenoestrogens have increased. However, phenomena that parallel one another do not necessarily constitute a bonafidecause and effectrelationship (Leatherland 1992).

Some of the postulated impacts to wildlife include decreased fertility in birds, fish, shellfish, and mammals (Stone 1994; Jobling and Sumpter 1993; Golub et al. 1991); decreased hatching success in birds, fish, and turtles (Fox 1992; Walker and Peterson 1992; Gross and Guillette 1993); gross birth deformities in birds, fish, and turtles (Raloff 1994; Klein and Herbst 1993); metabolic abnormalities in birds, fish, and mammals (Stone 1994; Reijnders and Brasseur 1992); defeminization and masculinization of female fish and birds (Davis and Bortone 1992; Schmidt 1994); and demasculinization and feminization of male fish, birds, and mammals (News & Comments 1993; Fox 1992). The pattern of observable effects reported in these studies varies among species and among compounds. In general these studies suggest: (1) the chemicals of concern may have entirely different effects on the embryo, fetus, or perinatal organism than on the adult; (2) the effects are most often manifested in offspring, not in the exposed parent; (3) the timing of exposure in the developing organism is crucial in determining its character and future potential; and (4) although critical exposure occurs during embryonic development, obvious manifestations may not occur until maturity (Colborn and Clement 1992; Schmidt 1994).

Wildlife populations, and each individual organism that makes up the population, are potentially exposed, throughout the population's or individual's lifecycle, to a wide variety of toxic chemicals, including the xenoestrogens, and possibly many combinations of the same. The recent literature indicates that few, if any, habitats can be considered free of industrial and/or agricultural pollution. The reports in the scientific literature suggest that no part of the food web is immune to the possibility of deleterious interactions with the xenoestrogens. Within aquatic systems, even the minute organisms that form part of the lower portions of the food web (e.g., water fleas (*Daphnia*) in fresh water and copepods in oceanic habitats) have been reportedly affected by xenoestrogens (Fox 1992). Historical data indicate that the proportion of males in some *Daphnia* populations has declined concurrently with the beginning of the introduction of xenoestrogens into the environment in the early 1940s. Organochlorine pesticides reportedly can reduce *Daphnia* productivity by approximately 15% at body concentrations of 5 parts per

billion (ppb) (Dodson 1993). Within the marine ecosystem, scientific reports indicate that egg production in copepods can be lowered and reproduction abnormalities in sea stars (*Asteria rubens*) can be induced by exposure to PCBs (Reijnders and Brasseur 1992).

MARINE ECOSYSTEMS

Marine habitats comprise complex ecosystems and contain mixtures of chemicals complicating definitive statements of cause and effect relationships between chemical exposure and reproductive abnormalities in wildlife (Hose 1993; Schmidt 1994). Although the demonstration of reproductive impairment has been controversial, the early life stages of fish have been demonstrated to be more sensitive than adult fish to the lethal effects of PCBs and presumably to other xenoestrogenic chemicals (Hose 1993; Walker and Peterson 1992). Decreases in fecundity and fertility in white croaker at a site in San Pedro Bay (southern California) have been attributed to DDT contamination of the bay. The study concluded that 3.8 ppm DDT in white croaker was a limiting threshold above which the fish did not spawn (Hose 1993). Reproductive impairment comprised destruction of early oocytes (Hose 1993) and abnormal ovarian development as well as decreased plasma estradiol levels. Other research has described PCB induced inhibition of gonadal recrudescence and reduced levels of plasma estradiol in female English sole (*Parophrys vetulus*). However, it is important to recognize that other contaminants could also be involved. PCBs have been implicated in disrupted gonadal maturation and altered steroid levels in other marine fish as well: Atlantic cod (*Gadus morhua*); Atlantic croaker (*Micropogonias undulatus*) and winter flounder (*Pseudopleuronectus americanus*). The authors of one review article (Reijnders and Brasseur 1992) state that although disturbances, postulated to be linked to xenoestrogens and hormonal imbalance, in the early phase of reproductive cycles in marine organisms, are amply documented, no clear correlation between residue levels and the observed effect could be established. In many cases, the mode of action is only partly explained.

Xenoestrogenic effects are observed throughout all trophic levels in the marine ecosystem, ranging from zooplankton to top predators such as seals and polar bears (Schmidt 1994; Reijnders and Brasseur 1992; Colborn and Clement 1992). Carnivorous wildlife are subject to bioaccumulation of xenoestrogens, and numerous other toxic chemicals, that have been linked to reproductive failures in other marine and fresh water species (Ramsey 1993; Schmidt 1994). Polar bears (Ramsey 1993); dolphins (Lahvis et al. 1993); porpoises (Reijnders 1986); seals (Reijnders 1986; Reijnders and Brasseur 1992); green turtle (Klein and Herbst 1993); beluga whale (DeGuise et al. 1993; DeGuise et al. 1993); cormorants (Fox 1992); white-faced ibis (Fox 1992); gulls (Fox 1992); and terns (Fox 1992) have all had a suite of reproductive abnormalities suggested to be linked to xenoestrogenic chemicals including organochlorine pesticides and PCB congeners in various locations. Reijnders (1986) reported that common seals (*Phoca vitulina*) fed with fish containing PCBs, at an average daily intake (during about 2 years) of 1.5 mg PCBs, exhibited a significantly lower reproductive success in comparison to seals with an average daily intake of 0.22 mg PCBs.

FRESH WATER ECOSYSTEMS

The wildlife species of fresh water ecosystems have reportedly exhibited reproductive abnormalities similar to those seen in marine organisms, and again the xenoestrogens and other xenobiotic chemicals (chemicals that are foreign to an organism or biological system) are suggested as causal agents (Colborn and Clement 1992; Schmidt 1994). Research on fish, in England, and on eels, in France, found downstream of sewage treatment plants demonstrated an altered reproductive physiology in both species (Raloff 1994; News & Comments 1993). The researchers found the protein vitellogenin in blood samples of male fish (rainbow trout and carp) exposed to sewage plant effluent. Normally only female fish produce this protein. The researchers have suggested a link between the abnormalities and ethynyl estradiol (EE), which is found in the urine of women taking oral contraceptives, or the degradation

products of surfactants of common domestic detergents. However, the investigators are not certain if the wild fish populations are suffering any real harm due to this xenoestrogen exposure.

Laboratory research has shown that concentrations of EE as low as 0.1 nanogram per liter of water can cause a significant increase in the fish's production of vitellogenin (Raloff 1994). The breakdown products of alkylphenol-based surfactants, nonylphenols, are considered good candidates to account for the estrogenic effects noted in the study with rainbow trout and carp because these chemicals are nearly ubiquitous in the aquatic environment and because they were present at relatively high concentrations in the rivers studied. Concentrations of nonylphenols of 1 to 50 µg/L are typical of waters in England and Europe (Raloff 1994) U.S. concentrations tend to fall below 1µg/L (Talmadge 1994).

The nonylphenols are comparatively resistant to degradation and they can bioconcentrate (due to their lipophilicity and persistence) in fish which may increase the probability of them producing physiological effects (Raloff 1994). However, while bioconcentration

and bioaccumulation have been observed in some aquatic species, excretion of alkylphenols appears to be rapid when the organisms are returned to clean water (Talmage 1994). Other research (Jobling and Sumpter 1993; Talmage 1994) has demonstrated that alkylphenol-based surfactants are normally present in raw sewage; and many of the biodegradation products of these compounds can be both persistent and present in effluent and in the receiving water.

Soto et al. (1992) reported that alkylphenols are estrogenic in mammals and that nonylphenol has between one one-millionth and one one-hundred-thousandth the potency of 17β-estradiol, about the same as DDT and kepone. Jobling and Sumpter (1993) reported that, in a laboratory (*in vitro*) bioassay, several degradation products of alkylphenol-based surfactants are weakly estrogenic (about two ten-thousandths to two ten-millionths the potency of human estrogen) to rainbow trout (*Oncorhynchus mykiss*) and because of bioaccumulation would be more potent in living fish (*in vivo*) than in the laboratory bioassay

Surfactants are used in detergents, personal care and household cleaning products and are also used by the oil, textile, food and mining industries. Due to their widespread use and persistence, they have been detected in river water, drinking water, sediments and sludge-amended soils. The chronic and sublethal effects vary with the surfactant, the degradative products and the test species (Lewis 1991). Alkylphenol ethoxylates showed lowest effect concentrations at 2.4 mg/L for mussels (*Mytilus edulis*), exhibited by larval growth and development abnormalities (Lewis 1991). Talmage (1994) reported that the toxicity values of commercially available alkylphenol ethoxylates fall between 4 and 14 mg/L for most species of fish. However, sublethal effects varied greatly with surfactant and species. The age of test species and experimental conditions affect toxicity, sublethal expressions, bioaccumulation, and bioconcentration parameters. A review paper of the risk of adverse environmental impact of alkylphenols and their ethoxylates concluded that, the risk of adverse environmental impact is low based on (1) extensive biodegradation/removal at wastewater treatment plants, (2) low concentrations in 30 U.S. rivers at locations most likely to contain significant amounts (U.S. concentrations tend to fall below 1 µg/L), (3) a substantial margin of safety between "worst case" river water concentrations and sublethal toxic effects, and (4) the absence of significant accumulation of nonylphenol and nonylphenol ethoxylates in the water columns, interstitial water, sediment, and fish (Talmage 1994).

In the past 20 years, PCB reproductive toxicity has been investigated in a large number of studies of humans, laboratory animals, and wildlife. Commercial production of PCBs began in the U.S. in 1929. In retrospective studies of museum specimens of Lake Michigan fish, PCB residues first appeared in 1949, and levels increased progressively through 1965, the last year studied (Golub et al. 1991). Lake trout, the only salmonid native to the Great Lakes, were nearly eliminated from the Great Lakes ecosystem by a combination of factors including overfishing, sea lamprey predation, habitat degradation and long-term exposures to environmental pollutants, such as PCBs, DDT and dioxins (Schmidt 1994). Lake trout eggs

are extremely sensitive to chemical pollutants. Studies have correlated embryonic mortality in lake trout with levels of PCBs in eggs and the adults.

The extinction of other Great Lakes fishes, such as lake herring, lake whitefish and deepwater sculpin have been suggested to be correlated with the increased dumping of PCBs and other toxic wastes in the Great Lakes region, however, this has not been demonstrated conclusively. The Pacific salmon, introduced into the Great Lakes 30 years ago and restocked annually, show reproductive and physiological abnormalities possibly related to the effects of xenobiotic chemicals such as PCBs (Schmidt 1994). Leatherland (1992) states that because of the biomagnification characteristics of food webs, identification of potentially toxic agents is more likely to occur by analysis of tissue burdens of xenobiotics, than by analysis of lake water samples. An example of this biomagnification is the comparison of the levels of PCBs in Lake Ontario coho salmon and Lake Ontario water based on levels found in the 1970s. Two to three hundred grams of salmon could have contained the same amount of PCB as several million liters of lake water. Laboratory studies by Walker and Peterson (1992) demonstrated that part per trillion (ppt) concentrations of PCBs in lake trout (*Salvelinus namaycush*) and rainbow trout (*Oncorhynchus mykiss*) eggs manifest toxicity by sac fry mortality associated with yolk sac edema and hemorrhages. One report states that the pallid sturgeon, an endangered fish native to the Missouri and Mississippi Rivers, has not had any record of reproduction for 10 years (Raloff 1994). High concentrations of PCBs and DDT that have been found in some pallid sturgeon have led some researchers to suspect these xenoestrogens as causing the lack of reproduction noted for this species. However, the reduction of the pallid sturgeon's habitat by damming and straightening the rivers also is a possible cause to the species' lack of reproduction.

Some fresh-water ecosystems also show suspected developmental, behavioral and physiological abnormalities related to xenoestrogenic and/or xenobiotic chemical compounds. The scientific literature suggests that few, if any, species of the food web are unaffected by these metabolic disrupters; in fact it is suggested that the problem may manifest itself more in the "higher" levels of the food web (Leatherland 1992). Environmental pollutants have been suggested as, but not proven to be, the cause of declines or extinction of amphibian populations in the western U.S. The suggestion is that the declines or extinction have been associated with bacterial diseases, for example "Red-leg", caused by a xenobiotically compromised immune system, but again, the suggestion is not corroborated with data (Carey 1993). Turtles and alligators from Lake Apopka, Florida were demonstrated to have sexual reproductive abnormalities related to high concentrations or heavy contamination of DDT in the lake (Gross and Guillette 1993; Guillette et al. 1993; Raloff 1994). Reproduction in bald eagles around the Great Lakes starts to fall when PCBs in their bodies exceed 4 to 6 parts per million (ppm) or DDE (a degradation product of DDT) exceeds 1 ppm, and eggs with PCB concentrations as high as 120 ppm have been seen in the Great Lakes eagle populations (Raloff 1994). In addition to DDT, Great Lakes bald eagles carry elevated concentrations of other compounds, such as chlordane, that are known endocrine disruptors. Terns nesting near a toxic waste site contaminated with PCBs were reported to have a high percentage of male embryos with varying degrees of abnormal or "feminized" organs (Raloff 1994) and gull eggs treated with DDT exhibited the same array of feminized sex organs in the hatchlings as did DDT-contaminated Western gulls on Santa Barbara Island, CA (Raloff 1994). Reduced productivity due to DDT or DDE contamination also has been reported in white-faced ibis, black-crown night heron, and green-backed heron (Schmidt 1994).

Additional basic research is needed to determine if low environmental concentrations of xenoestrogens can result in wildlife abnormalities (Stone 1994). Carey (1993), regarding amphibians, states, "it is virtually unknown how environmental pollutants, acid-rain, or other man-made environmental changes affect immune function and vulnerability to disease in larvae and metamorphosing young." This statement, perhaps, may be more universally applied when considering low environmental concentrations of xenoestrogens and their potential impact on the lifecycle of any organism (see Stone 1994).

5 SUMMARY

A large number of chemicals have been identified as having the potential to produce adverse reproductive outcomes in humans and animals. Those chemicals that disrupt the metabolism or effects of the sex hormones of the endocrine system have been collectively referred to as environmental estrogens or xenoestrogens. Many of these chemicals are chlorine-based. Although adverse reproductive effects have been associated with many non-chlorinated chemicals such as heavy metals (i.e., lead, cadmium and mercury); carbamate, triazine and other types of pesticides; styrene; and phthalates, most concern has been focused on the chlorine-based chemicals (e.g., organochlorine pesticides and PCBs) because of their widespread use and their persistence in the environment.

Organochlorine chemicals have been used in a variety of household, commercial and industrial products, including insecticides, herbicides, coolants, lubricants, paints, inks, waterproof coatings, carbonless copy paper, and wrapping paper for citrus fruit. The use of 16 of these organochlorine chemicals (i.e., PCBs and many organochlorine pesticides) has been canceled in the United States because of concerns about their health effects on both humans and animals. For DDT (and its by-products) and PCBs, ambient environmental concentrations and body burdens have reportedly declined since the 1970s and early 1980s when the widespread use of these chemicals was halted. Eighteen organochlorine chemicals or groups of chemicals are measured as part of the Laguna Plant's quarterly monitoring program or are being measured as a part of the reclaimed water quality study that is being prepared for the Subregional Wastewater Project (Table 2). The results of these analyses will be presented in the Reclaimed Water Quality Technical Report and will be used in a screening human health and ecological risk assessment.

The other potential environmental estrogens (i.e., the non-organochlorine chemicals) may be found in a variety of common commercial, industrial and household products, including pesticides, paints, plastics, wood products, insect repellents, cosmetics, rubbing alcohol, liquid soap, detergents, decorative inks, lacquers, industrial and lubricating oils, birth control pills, and defoaming agents used during paper and paperboard manufacture. Of these chemicals, twelve are regularly measured as a part of the Laguna Plant's quarterly monitoring program or are being measured as a part of the reclaimed water quality study that is being prepared for the Subregional Wastewater Project (Table 2).

Nine pesticides and the synthetic and natural estrogens are not on either list of analytes.

Among the nine unanalyzed pesticides only dicofol, benomyl, and mancozeb have been used in quantities greater than 1,000 pounds per year in Sonoma County in recent years. Because of the high usage of benomyl and mancozeb and the unknown half-life of dicofol, it is not possible to exclude the possibility that these chemicals may occur in

detectable concentrations in the Laguna Plant influent or effluent. Among the synthetic and natural estrogens, water soluble forms of ethinylestradiol and the natural estrogens may be present in the Laguna Plant influent. While susceptible to degradation to less water soluble forms by the water treatment process, it is possible that these chemicals may occur in detectable concentrations in the Laguna Plant effluent.

The effects of exposure to estrogenic chemicals may be delayed in an individual or may appear in an exposed individual's offspring. Epidemiological data, such as that collected from human exposure to DES, indicate that adverse health effects may not manifest themselves for many years following exposure. Current regulatory levels are generally based on cancer risk, gene mutations, acute toxic effects, and visible birth defects and do not necessarily address the long term reproductive effects. Additional basic research about the specific adverse human health effects of environmental estrogens will be needed before it will be possible to quantitatively analyze the human health risk posed by environmental estrogens at low environmental concentrations. Such basic research is most appropriately conducted by a research institution and is beyond the scope of studies that could feasibly be performed for the Subregional Wastewater Project.

The evidence for adverse effects of environmental estrogens on wildlife has come from animal studies involving exposure to high levels of estrogenic chemicals in laboratory experiments or from environments contaminated by a large volume spill or industrial waste discharge. Published reports clearly indicate that high concentrations of xenoestrogens can alter the normal development of certain animal species but a cause and effect relationship between low concentrations of xenoestrogens and specific abnormalities in wildlife has not yet been conclusively demonstrated. The majority of the scientific literature dealing with the effects of low concentrations of xenoestrogens on wildlife fails to demonstrate direct evidence of cause and effect relationships, and instead offers speculative, or in some cases anecdotal, assumptions of cause and effect.

No data were available in the scientific literature concerning threshold levels (i.e., the lowest environmental concentrations in soil, air or water) that may induce estrogenic effects in wildlife or humans. Such data would be needed to evaluate any potential environmental estrogens found in air, water, soil or sediment samples. In addition, the effects of exposure to multiple, different estrogenic chemicals may be additive, synergistic or antagonistic. These potential, complex interactions make it difficult to draw conclusions from chemical analytical data alone without additional basic research into these interactions. Without these data from the scientific literature it is not currently possible to quantitatively evaluate chemical analytical data with respect to specific concentrations of potential environmental estrogens in soil, air and water. Until such information is available, the collection of additional analytical data, beyond that which has already been proposed for the quarterly monitoring program and the reclaimed water quality study of the Subregional Wastewater Project, is not warranted.

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The Appendix to this document is filed as
Exhibit J-1