Discussion of Specific Issues

This section of the Addendum contains responses to specific issues raised during public discussions on the proposed recycled water project. The discussions are organized as follows: a statement of the issue, its public concern, background information on the issue, findings and conclusions, and references used in the discussion. The author of each discussion is also identified.

Risk from Pathogens (James Crook, Ph.D., P.E.)

Statement of the Issue: Will use of recycled water for landscape irrigation project present a public health risk to the community from microbiological contaminants?

Public Concern: Recycled water used for landscape irrigation may contain pathogenic microorganisms that are harmful to humans.

Background: The infectious agents that may be present in untreated municipal wastewater can be classified into three broad groups: bacteria; parasites (protozoa and helminths); and viruses. There are several pathways (ingestion, inhalation, contact) through which an individual can acquire disease from recycled water - but only if pathogens are present in sufficient numbers to initiate disease in susceptible individuals. In order to insure public health protection where recycled water is used for landscape irrigation in urban areas, it is important to control pathogenic microorganisms by effective treatment and disinfection.

The California Department of Health Services (DHS) has adopted Water Recycling Criteria[1] to ensure that the use of recycled water for irrigation in urban areas does not impose undue risks to health. The criteria prescribe treatment processes, water quality limits, treatment reliability requirements, and use area controls for several types of recycled water applications, including the irrigation of residential landscaping, parks, playgrounds, and schoolyards. The criteria are based on research, demonstration studies[2,3], experience at operating recycling plants, attainability, and good engineering practice. They prescribe criteria that are intended to result in recycled water that does not contain measurable levels of pathogens. Although incidental, infrequent ingestion of tertiary treated reclaimed water would not present unreasonable health risks from microbial pathogens or chemicals, the DHS criteria also include use area requirements as an added safety measure to reduce potential ingestion of the recycled water. Measures include: confinement of runoff to the approved recycled water use area unless otherwise approved by the regulatory agency; prohibition of reclaimed water spray, mist, or runoff in dwellings, designated outdoor eating areas or food handling facilities; protection of drinking water fountains against contact with recycled water; signs at sites using recycled water that are accessible to the public; prohibition of hose bibs on recycled water piping systems accessible to the public; and conformance to cross connection regulations. In addition, the California Health and Safety Code requires a color-coded labeling or marking system for pipes and appurtenances that clearly distinguishes recycled water from potable water.

The ability to reliably produce recycled water that is safe for the intended use has been demonstrated throughout California at full-scale facilities having the same treatment

processes, water quality limits, and reliability features as those at the SBSA wastewater treatment plant. For example, during a 10-year study[4] of 6 tertiary treatment plants (similar to the SBSA plant) operated by the County Sanitation Districts of Los Angeles County, only 1 of 590 samples of recycled water was found to contain a measurable level of enteric viruses, while a 1997-1999 study[5] at the Salinas Valley Reclamation Project did not detect any *E. coli* 0157:H7, *Cyclospora*, *Salmonella*, helminth ova, viable *Giardia*, or culturable natural (*in situ*) viruses. Only an extremely low number of *Cryptosporidium* (in only two instances) was detected in any of the tertiary treated reclaimed water samples, and it was not determined whether the oocysts were viable or nonviable.

Risk assessment models have been used to estimate human health risk associated with various applications of recycled water. For example, one study[6] directed at golf course irrigation using tertiary effluent (similar to that from the SBSA plant) indicated that the annual risk of contracting at least one infection from exposure to the water was less than that considered acceptable for drinking water. Maximum contaminant levels for drinking water are typically based on a one in ten thousand ($1x10^{-4}$) acceptable risk level. A similar study[7], which took treatment reliability into account, determined that the annual risk of enteric virus infection of using tertiary recycled water for golf course irrigation ranged from 1.4 in one million to 5.5 in ten million episodes ($1.4x10^{-6}$ to $5.5x10^{-7}$) assuming a 95% confidence level. The apparent risk level from virus infection is approximately 100 to 1,000 times safer than the California health based standards. Another study[8] conducted at the Irvine Ranch Water District (again, a treatment facility with the same treatment and quality requirements as those at SBSA) using an epidemiologically based risk assessment model, determined that swimming in an impoundment filled recycled water did not increase the predicted incidence levels above those obtained when the impoundment was filled with water of non-sewage origin.

Exposure to recycled water in spray form (aerosols) has often been cited as a public health concern. A review of the scientific literature does not indicate that there have been any reported documented disease outbreaks in the U.S. resulting from spray irrigation with disinfected recycled water, including recycled water that has received considerably less disinfection than that provided at the SBSA facility.

There are urban irrigation projects in several states (e.g., Arizona, Florida, and Texas) that have less restrictive treatment and disinfection criteria than those imposed on projects in California, and the literature reviewed did not reveal any documented instances of illness resulting from recycled water in these or other states. This is particularly significant in Florida's case, since Florida has had large-scale dual water systems providing recycled water for irrigation throughout communities since the mid-1970s. St. Petersburg, for example, has been using recycled water for multiple uses within the city since 1977 and currently has more than 10,000 individual residential customers where recycled water is used for lawn irrigation. The Irvine Ranch Water District (IRWD) is one example of a large dual water system in California. IRWD has been in operation since 1977 and currently uses about 15 million gallons per day of recycled water for several applications, including landscape irrigation of residential lawns, parks, and schoolyards. The County Sanitation Districts of Los Angeles County (which has the same recycled water treatment and quality

requirements as SBSA) also provides large amounts of recycled water for landscape irrigation. The final draft of a report by the California Department of Water Resources Recycled Water Task Force states that, in 2000, approximately 80,000 acre-feet (70 million gallons/day) of recycled water was used for landscape irrigation in the state.

A correlation can be made between EPA's recommended microbial standard of 126 *E. coli*/100 mL for recreational waters[9] (swimming allowed with some ingestion anticipated) and recycled water. EPA's standard is much less restrictive than the total coliform standard of 2.2/100 mL required by DHS for irrigation with recycled water in urban areas and met in the SBSA recycled water (*E. coli* is a subset of the total coliform group). Even though there will be no body contact activities associated with the use of recycled water in Redwood City and only incidental contact with the water, the microbial quality of the recycled water clearly is superior to the quality recommended by EPA for recreational waters.

Findings: Pathogens are present in untreated municipal wastewater but can be reduced to immeasurable levels by conventional wastewater treatment processes. There have been no documented cases of illness in California (or elsewhere in the U.S.) resulting from the use of recycled water to irrigate urban areas. The SBSA wastewater treatment plant conforms to all of the regulations contained in the California DHS *Water Recycling Criteria*, which are conservative from a public health standpoint.

Conclusion: Existing data indicate that the use of recycled water from the SBSA wastewater treatment plant for landscape irrigation in urban areas will be safe from infection or disease associated with pathogenic microorganisms.

References:

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5. Jaques, R.S., G.M. Antonz, R.C. Cooper, and B Sheikh. 1999. Pathogen Removal Effectiveness of a Full-Scale Recycling Plant. In: *Proceedings of WEFTEC '99,* October 9-13, 1999, New Orleans, Louisiana.

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Pharmaceuticals and Endocrine Disruptors (James Crook, PhD, P.E.)

Statement of the Issue: Do pharmaceuticals and endocrine disruptors present a health risk if recycled water is used for landscape irrigation?

Public Concern: Recycled water used for landscape irrigation may contain pharmaceutically active compounds and endocrine disruptors that could be harmful to humans.

Background: There has been a great deal of interest and, in some cases, concern, regarding human health effects associated with pharmaceuticals, hormones, and other organic wastewater contaminants. Chemicals that interfere with endocrine systems of humans and wildlife are termed endocrine disruptors (EDCs). Chemicals and pharmaceuticals in general that elicit a pharmaceutical response in humans are termed pharmaceutical active compounds (PhaCs). It should be noted that EDCs and PhaCs are not mutually exclusive classifications, as some, but not all, EDCs are also PhaCs. Endocrines are chemicals used by organisms to regulate important metabolic activities, such as ion balance, reproduction, basal metabolism and fight or flight responses, through changes in hormones secreted by the thyroid, parathyroid, pituitary, adrenal, sex, and other glands. Research has identified more than 60 pharmaceutically active compounds that impact the endocrine system of animals or humans in nanogram/liter (ng/L), i.e., one part per trillion, or lower concentrations in the ecosystem. In addition, pharmaceuticals and personal care products are sometimes called PPCPs, which comprise a very broad, diverse collection of thousands of chemical substances, including prescription and over-the-counter drugs, fragrances, cosmetics, sun screen agents, diagnostic agents, biopharmaceuticals, and many other compounds.

Most of the research to date has been directed at the presence, concentration, and effects of pharmaceuticals, personal care products, and endocrine disruptors – or their metabolites – on the aquatic environment, where these constituents have been shown to have adverse effects on aquatic animals such as frogs and fish. Less is known about the presence, concentration, and human health effects (including additive/synergistic effects) associated with these compounds resulting from long-term ingestion from potable waters and concerns have been raised.

Much of the current concern is based on the results of a nationwide reconnaissance of the occurrence of organic contaminants conducted by the U.S. Geological Survey in 1999-2000[1]. Samples collected from 139 streams in 30 states for 95 pharmaceuticals, personal care products, and known or potential endocrine disruptors found that 80% of the streams sampled contained at least one of the chemicals. While measured concentrations were generally low and rarely exceeded drinking water guidelines, drinking water advisories, or aquatic life criteria, many of the compounds do not have such guidelines established[1].

Many commonly used pharmaceuticals in the United States are ubiquitous in wastewater effluents. In conventional wastewater treatment plants, they can be removed, or reduced in concentration, by microbial degradation, adsorption to particulates that are removed during

wastewater treatment, or by biotransformation. Research on wastewater samples collected at several wastewater treatment plants in California indicated that secondary effluent contains estrogenic hormone concentrations comparable to those that cause vitellogenesis (i.e., feminization) in fish and that filtration of secondary effluent (i.e., tertiary treatment) removes approximately 70% of the hormones from secondary effluent[2]. For example, the synthetic oral contraceptive 17α-ethynyl estradiol occurs generally at concentrations less than 7 ng/L in wastewater effluent. This compound is suspected, in combination with the steroidal estrogens 17β-estradiol and estrone, of causing vitellogenin production (feminization) in male fish. While conventional secondary and tertiary treatment efficiently removes some pharmaceuticals, removal or reduction of others is highly variable[4,5].

The release of pharmaceuticals and endocrine disruptors through municipal wastewater into the environment is potentially associated with a human health risk where water is subsequently used to augment a drinking water supply. It should be remembered that recycled water used for urban irrigation is not intended to be a consumed; thus, the concerns associated with ingestion of water containing these contaminants do not apply to the Redwood City project. A review of the scientific literature does not provide any information indicating that pharmaceuticals and endocrine disruptors become concentrated on vegetation or in soil via irrigation with recycled water. Drugs detected in the environment are generally in the µg/L - ng/L (parts per billion - parts per trillion) range and many have short half-lives (i.e., they do not persist for long periods in the environment) and may not pose much acute risk[3]. Also, most pharmaceuticals and endocrine disruptors have low volatility or are nonvolatile and, thus, would not be expected to present a health concern from inhalation at spray irrigation sites.

Findings: Pharmaceuticals and endocrine disruptors in water have been shown to have adverse effects on aquatic animals. Human health effects associated with long term ingestion of these types of compounds – at the low concentrations potentially present in drinking water – have not been documented and are uncertain at this time. Contact with – or infrequent/inadvertent ingestion of – tertiary treated recycled water containing low levels of pharmaceuticals and endocrine disruptors would appear to present substantially less risk than that associated with long term ingestion of drinking water containing similar levels of such substances.

Conclusion: There are no data indicating that the use of recycled water from the SBSA wastewater treatment plant for landscape irrigation in urban areas presents a health risk from pharmaceuticals or endocrine disruptors.

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Carcinogenic Compounds (James Crook, Ph.D., P.E.)

Statement of the Issue: Do carcinogenic compounds present a health risk if recycled water is used for landscape irrigation in an urban area?

Public Concern: Recycled water used for landscape irrigation may contain carcinogenic compounds that are harmful to humans.

Background: Since chlorine is used for disinfection at the SBSA wastewater treatment plant for disinfection, there is the possibility that chlorine will react with organic and inorganic constituents in the water to create disinfection byproducts (DBPs) that are potentially harmful upon ingestion of the water. The DBPs of concern in drinking water include trihalomethanes, haloacetic acids, bromate, and haloacetonitriles. Data from various studies indicate that tertiary treatment of municipal wastewater (similar to that in place at SBSA) removes or reduces many of the compounds that react with chlorine to form DBPs and, thus, reduces the potential for DBP formation. DBP levels – as well as pesticide and heavy metal levels – in tertiary treated wastewater generally are below maximum contaminant levels (MCLs) in drinking water standards[1]. A review of the scientific literature provided no information on accumulation of DBPs on turf or soil, but many DBPs are volatile and would not be expected to accumulate on turf or in soil. While it is true that some DBPs remain unidentified and poorly characterized toxicologically, it should be noted that: (1) risk levels for contaminants in drinking water are based on consumption of 2 liters/day (0.5 gallons/day) of water by a 70-kilogram (150-pound) person for 70 years; and (2) recycled water in Redwood City will be used only for nonpotable applications.

N-Nitrosodimethylamine (NDMA) is an example of a probable carcinogen that has been identified in both recycled water and drinking water. In the past, NDMA was a key ingredient in the production of 1,1-dimethylhydrazine, a component of rocket fuel. It has also been used in battery, rubber, and polymer manufacturing, and as an additive to some lubricants. It is no longer produced commercially. NDMA is semi-volatile and has a high chronic and acute toxicity; levels needed to cause acute toxicity are much higher than those that have found in tertiary treated recycled water. It is classified by EPA as a probable human carcinogen with a one in a million (1×10^{-6}) lifetime cancer risk at 0.7 nanograms per liter (ng/L), i.e., 0.7 parts per trillion. This level is based on elicited *in vitro* genotoxicity and carcinogenicity effects in laboratory animals conducted over the past two decades. EPA has not adopted a primary drinking water standard for NDMA. The California DHS has set an action level of 10 ng/L in drinking water. Action Levels are health based advisory levels established by the California Department of Health Services for chemicals that lack maximum contaminant levels.

Several water supply agencies in California have observed the formation of NDMA after chlorine disinfection of source water[2]. While chlorination of surface waters used for drinking typically results in the formation of less than 10 ng/L NDMA, concentrations in tertiary treated wastewater can be much greater. The observation of NDMA is due to improvements in analytical techniques that have enabled detection of concentrations as low as 1 ng/L rather than changes in treatment techniques. In order to put the concentration

and health risk of NDMA in water in perspective, it should be noted that NDMA is common in food products such as fish, cheese, milk, cured meats, and beer. Average concentrations of NDMA measured in food have been shown to range from 90-100 ng/L for whole milk, 2,600-2,700 ng/L for bacon, and 50-7,700 ng/L for various beers[3]. It can also be found in tobacco smoke, cosmetics, and rubber products.

Findings: Several disinfection byproducts, such as the trihalomethanes, and other chemical contaminants are known to be carcinogenic upon long-term ingestion; however, a review of the literature provides no indication that they have been implicated as having any adverse effects resulting from nonpotable uses of recycled water, such as landscape irrigation. Most of these contaminants are present in tertiary treated wastewater at levels that are lower than maximum contaminant levels specified in drinking water standards. Fears of chronic health effects (associated with long term ingestion of water containing DBPs or other carcinogens) are unfounded for recycled water projects directed at nonpotable applications of the water, since there will be no long term ingestion of the recycled water.

Conclusion: There are no data indicating that the use of recycled water from the SBSA wastewater treatment plant for landscape irrigation in urban areas will present a health risk to humans from DBPs or other carcinogens.

References:

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3. Metropolitan Water District of Southern California. 2000. *Report on N-Nitrosodimethylamine (NDMA) in Metropolitan's Treated Water.* May 30, 2000, Water Systems Operations, Metropolitan Water District of Southern California, Los Angeles, California.

Exposure to Children (James Crook, Ph.D., P.E.)

Statement of the Issue: Does the use of recycled water used for landscape irrigation present risks to children?

Public Concern: Recycled water used for landscape irrigation may contain microbial pathogens or chemical contaminants that are harmful to children.

Background: The issue discussions above conclude that landscape irrigation in Redwood City using recycled water from the SBSA wastewater treatment plant will not present health risks measurably different than those resulting from the use of potable water. These conclusions apply to all residents that live within or close to the proposed irrigation sites, including children. Recognizing that children may have more intimate contact with grounds irrigated with the recycled water, a further discussion documenting their safety is provided.

Children playing in turf irrigated with recycled water could come in contact with pathogenic organisms (if present in the water) or chemical contaminants by: ingestion of grass or soil; contact with turf, soil, or objects wet with recycled water or containing residue from recycled water; by inhalation of recycled water aerosols during spray irrigation; or by contact or ingestion of the recycled water directly from puddles, hose bibbs or other means. As stated in the preceding issue papers, pharmaceuticals and disinfection byproducts would not be expected to accumulate to levels on turf or in soil to levels that present health risks.

Additional safety measures will be imposed on the recycled water distribution system by Redwood City, including: color-coding all recycled pipes, valves, and appurtenances; prohibition of hose bibs or above ground distribution piping systems to reduce the chance of misuse; prohibition of ponding and runoff of the recycled water; irrigation during off-hours to limit potential contact with the water; and inspection and surveillance activities.

The authors of the California DHS *Water Recycling Criteria* recognized during development of the criteria that the mechanisms for contact, ingestion, or inhalation described above can occur. They thus adopted criteria requiring a high degree of treatment and reliability to assure that recycled water used for landscape irrigation in urban areas is free of measurable levels of pathogenic microorganisms. California's water recycling criteria are among the most conservative in the U.S., and the SBSA facility is subject to those restrictive criteria. The literature reviewed did not reveal any documented instances of disease resulting from any of the many landscape irrigation projects in California or elsewhere in the U.S., where there are hundreds of sites using recycled water for the irrigation of parks, playgrounds, school yards, and residential lawns.

As stated in the preceding issue papers, the recycled water produced at the SBSA facility will meet most of the drinking water standards. Drinking water standards for most regulated contaminants are based on long-term ingestion, i.e., 2 liters/day (0.5 gallons/day) for 70 years by a 70-kilogram (150-pound) person. Therefore, infrequent incidental ingestion

of contaminants that may be present in the recycled water would not be expected to present acute or long term adverse health consequences at the concentrations likely to be present.

Findings: The recycled water from the SBSA wastewater treatment plant is subject to strict criteria to insure that it will not contain measurable levels of pathogenic microorganisms. Data from the SBSA facility indicate that all requirements are consistently met. Children's activities that may result in contact with the recycled water are expected and the water quality criteria to be met take this into account. A review of the scientific literature did not provide any documentation of illness or disease to children (or adults) resulting from any recycled water landscape irrigation project in the U.S.

Conclusion: The use of recycled water from the SBSA wastewater treatment plant for landscape irrigation in urban areas will not present health risks to children that are measurably different than any risks associated with irrigation using potable water.

Safety of Recycled Water for Irrigation of Landscaping (Bahman Sheikh, Ph.D., P.E.)

Statement of the Issue: Is disinfected tertiary recycled water safe for irrigation of residential landscaping, parks, playgrounds and/or schoolyards?

Public Concern: Recycled water used for landscape irrigation could be harmful to humans if skin contact or ingestion occurs.

Background: The issue summarized above can be answered using at least four different approaches:

- **Public health approach** based on treatment technology, disinfection capability, and the documentation available to the public on hundreds of similar treatment systems currently in operation.
- **Exemplary approach,** based on the numerous other residential areas in California, Florida and other localities using similar quality recycled water over a long period of time.
- **Environmental contextual approach,** acknowledging the numerous sources of contamination of the landscape (domestic and wild animals, fertilizers, pesticides, herbicides, human activity) in contrast to the thoroughly disinfected recycled water supplied in closed pipes for irrigation.
- **Comparative approach,** reasoning that use of recycled water for landscape irrigation is on a lesser level of human exposure than its use for vegetable crop irrigation, where the vegetables are marketed for use in salads and other produce intended for raw and fresh consumption by humans—irrespective of their age, health, or immunity status.

In this discussion, the latter approach is adopted, focusing specifically on the experience gained over the last five years in Monterey County with use of disinfected tertiary recycled water for irrigation of raw-eaten food crops, such as lettuce, strawberries, celery, cauliflower, broccoli, etc. The recycled water used in Monterey County for irrigation of fresh-eaten vegetable crops is disinfected tertiary reclaimed water, with the same quality characteristics as the recycled water currently produced by SBSA serving the City of Redwood City's First Step pilot project.

Other farming areas using similar quality recycled water for irrigation of fresh vegetables are located in Sonoma County and in Orange County.

Motivation, History and Pilot Project

The Monterey Regional Water Pollution Control Agency (MRWPCA) was formed in the early 1970s as a joint-powers agreement among eight cities[3], Monterey County, and Fort Ord, to provide wastewater treatment, water reclamation, and effluent disposal for the

[3] Cities represented in the MRWPCA are: Salinas, Pacific Grove, Monterey, Castroville, Moss Landing, Del Rey Oaks, Seaside, and Marina. Another member, Fort Ord has since been converted from military to civilian use, under the control of the California State University system.

entire Northern Monterey region. The U.S. EPA planning and construction grants that resulted in the regional wastewater management scheme included a strong provision[4] for reclamation and reuse of the effluent for agricultural irrigation. This was motivated by the relatively rapid rate of advance of seawater intrusion into the two confined aquifers supplying fresh water for domestic and agricultural needs in Northern Monterey County.

Seawater intrusion is a coastal phenomenon, caused by overdraft of the aquifers resulting in a hydraulic reversal of low and movement of saline water inland deteriorating water quality in near-shore wells. An eleven-year pilot project was conducted to determine and demonstrate the safety of using disinfected tertiary recycled water for irrigation of such raw-eaten vegetable crops as celery, lettuce, broccoli, cauliflower, and artichokes. The research team that planned and conducted the pilot project included scientists in the fields of agronomy, biology, public health engineering, sanitary engineering, and survey research[5].

The research plan was discussed at length by local farmers, Monterey County Environmental Health Officer, Monterey County Farm Advisor, and other stakeholders who formed an oversight task force for the duration of the study. The task force reviewed project plans and made a large number of changes and additions to the research plan in order to make the results as credible and useful to the community as possible. The demonstration project was successfully concluded in 1987, conclusively demonstrating the safety of use of recycled water for irrigation of food crops. These results and conclusions were published in a comprehensive final report, in peer reviewed journals, and in numerous technical publications as well as presentations at national and international conferences. Some of these publications are included among the list of references at the end of this paper.

Overview - Project Implementation

The Monterey County Water Recycling Projects comprise a partnership between the Monterey County Water Resources Agency (MCWRA) and the MRWPCA. The partnership was formed in 1992, resulting in a $75-million project, including tertiary treatment facilities, a 45-mile pressurized distribution system, and 22 supplemental wells. The purpose of the projects is to supply irrigation water to about 12,000 acres of farmland in the northern part of Salinas Valley. The project began full-scale operation in 1998 and currently provides about 13,000 acre-ft per year of recycled water, with a peak production rate of almost 30 million gallons per day. The project is designed for ultimate capacity of 20,000 acre-ft per year with future provisions for storage of a portion of the winter flows for summer use. Crops grown currently include strawberries, lettuce, broccoli, celery, cauliflower, and artichokes.

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[4] These provisions arose from regional planning for long-term wastewater management in the basin, and were a result of recognition of the water shortage conditions in the region and the resultant over-pumping of the local coastal aquifers for domestic and agricultural uses. Reuse of reclaimed water was made a grant condition for the construction of the Regional Treatment Plant by the State Water Resources Control Board—as long as reuse was shown to be viable and economically feasible. Community involvement in the planning process was the key to the ultimate viability and feasibility of the water reuse plans.

[5] Key members of the research team included Dr. Bahman Sheikh (agronomist/soil scientist, project manager, and author of this paper), Professor Robert C. Cooper (public health scientist—now, Emeritus, UC Berkeley), and Dr. Robin Cort (biologist, environmental scientist, with Parsons Engineering Science).

Public and Customer Perception

Initially, the majority of the farming public was skeptical, with a few vocal and active opponents. However, the pilot project, known as Monterey Wastewater Reclamation Study for Agriculture (MWRSA) underwent significant efforts to educate them that recycled water meeting California's strict Title-22 regulations would be safe and wholesome for use in irrigation of food crops and for long-term productivity of their soils. Potential impact of use of recycled water on sale of the crops to the public was a more complicated concern to address. A market analysis, focusing on major wholesale buyers in large metropolitan areas in the United States (New York, Chicago, Los Angeles, San Francisco), discovered that the market was not affected by the type of irrigation water used, as long as the irrigation water met regulatory requirements and as long as no labeling of the produce was required. It was established that both of these conditions were met. Over the past five years, since the project has been fully operational, there have not been any negative impacts on the sale of crops to the wholesale or retail market. Neither has there been a need for labeling the produce as having been irrigated with recycled water[6]. Public health agencies agreed to waive the labeling requirements around the farms using recycled water, as long as access to private property was restricted with appropriate signs. This was deemed necessary to avoid giving the public the incorrect impression that use of the recycled water for irrigation of food crops was in any way unsafe.

The agencies involved have a detailed emergency plan ready for implementation in case there are reports that implicate the recycled water in any crop contamination cases that might arise in the future—either as a rumor, intentional misinformation, or an unrelated actual contamination. The plan has not yet been needed to be implemented—after five years of using recycled water. However, it is continually updated and kept in readiness mode, in large part to ensure the farmers that their investments will be protected.

Professor William Bruvold conducted extensive survey research throughout California in the 1970s to determine the level of public acceptance of various uses of recycled water. He found an inverse correlation between acceptance and the level of intimacy of use of reclaimed water. For example, use for drinking was least acceptable (44 percent) and irrigation of landscapes, including golf courses, most acceptable (98 percent). Irrigation of vegetables was acceptable to 88 percent of the respondents[7]. These early findings have since been confirmed by numerous recent surveys conducted in different parts of the country, including one in the City of San Francisco[8]. The percentage of San Franciscans surveyed who "strongly supported" or "moderately supported" using recycled water for watering yards in residential neighborhoods was 85 %.

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[6] Labeling of a product is required when a potential or actual health or safety hazard is proven; for example, sugar, fat, salt, nicotine, etc, are known to pose significant health risk to humans when consumed in food or tobacco products, hence the regulatory requirement for labeling of those products. No potential or actual public health risks have been proven with use of recycled water for any of its allowed applications; therefore, there has never been a regulatory requirement for labeling any agricultural product irrigated with recycled water.

[7] Bruvold, W. H., "Public Attitudes toward Reuse of Reclaimed Water", contrib. Univ. Calif. Water Resource. Cent. 173, 1972.

[8] Public Affairs Management; and Public Research Institute, San Francisco State University, "Assessing Public Opinion Regarding the Recycling of San Francisco's Treated Wastewater: A Survey of San Francisco Neighborhoods", August 1995.

The agencies involved in implementing the Monterey County Water Recycling Projects have prepared a number of public information materials and strategies to avert the possibility of rumors and unfounded fears from causing economic harm to the growers. These preparations include:

- Project educational brochures
- Worker safety video and brochure
- Produce seller training
- Updated marketing study
- Briefing State regulatory officials
- Briefing produce trade organizations
- Utilizing world-class experts as advisors on pathogens, soil science.
- User booklet
- Reference book
- Emergency response plan

Ensuring and Documenting Food Safety

From the beginning, food safety has been a primary concern of the MRWPCA and its partners in the water recycling project. In the early planning stages, a five-year pilot project was conducted in which the same crops were grown in rotation in 96 replicated randomized plots, some irrigated with recycled water and some with well water. At each harvest, samples were taken from the crops, soils, irrigation waters, and runoff water and analyzed for microbiological and chemical parameters[9]. Statistical tests were performed on the results to determine if any differences might be attributed to use of recycled water. Over the five year period, no such differences were observed and none of the monthly samplings of recycled water over the five-year period was positive for virus.

Prior to start of large-scale use of recycled water, additional food safety tests were conducted to determine the ability of the treatment process to inactivate pathogenic organisms such as *E. Coli* 0157:H7, *Cyclospora, Giardia, Cryptosporidium, Salmonella,* and *Shigella.* The results clearly indicated that the recycled water was as safe as any other source of irrigation water—if not safer than some[10].

Over the last five-year period of full-scale irrigation on 12,000 acres of vegetable crops with recycled water, samplings of recycled water for pathogenic microorganisms were continued, even though they were not required by the regulatory agencies—in this case, the Regional Water Quality Control Board and the Monterey County Environmental Health Department. This was done to further verify the continued safety of recycled water, and to give

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[9] Constituents and parameters tested on water, crops, and/or soil samples included the following: coliform (including fecal) bacteria, virus, parasites, pH, electrical conductivity, calcium, magnesium, sodium, potassium, carbonate as $CaCO_3$, bicarbonate as $CaCO_3$, hardness as $CaCO_3$, nitrate as N, ammonia as N, total phosphorus, chloride, sulfate, boron, total dissolved solids, biochemical oxygen demand (BOD), adjusted SAR, MBAS, cadmium, zinc, iron, manganese, copper, nickel, cobalt, chromium, lead, crop yield, shelf life, and a number of crop quality characteristics.

[10] Surface water sources commonly used for irrigation are routinely contaminated with animal droppings and runoff from adjacent areas. Tertiary recycled water, by contrast, is treated, disinfected, and delivered in closed pipes. Safety of recycled water, by now, has been corroborated by intensive studies in other areas, and by the track record of some 250 agencies producing and reusing similar disinfected tertiary recycled water.

additional confidence to the growers that they were receiving a reliably safe source of water. The results continue to corroborate earlier conclusions reached during the pilot study and during the run-up to full-scale irrigation with recycled water.

In addition to these intensive tests for food safety, the Monterey County Environmental Health Department has taken regular samples of recycled water for analysis in their own laboratories. The results of these independent tests have consistently corroborated those performed by the Agency and its contractors.

Over the past five years, thousands of tons of vegetables have been harvested from the 12,000 acres irrigated with disinfected tertiary recycled water and sold on the open market throughout the country. Wholesale buyers and markets are aware of the source of water used for irrigation of these crops, and as long as food safety is assured by the regulatory agencies, they have no qualms about buying and marketing the produce. Some of the produce they buy and market comes from foreign countries where the sources of irrigation water are of far lesser (and far less regulated and monitored) quality.

Even though a mandatory use ordinance is in effect in the service area, it has not been necessary to invoke the mandate. Within the 12,000 acres irrigated with recycled water, 95 percent of the growers voluntarily use recycled water for irrigation.

Water Quality Assurance
An enhanced water quality assurance program has been initiated with the following components:

- Source Control
- In-Plant Monitoring
- Equipment Redundancy
- Water Storage Monitoring
- Distribution System Monitoring
- Worker Safety Program
- Product Safety Testing
- Water Quality Advisory Committee

Findings: Over the five-year operational phase of the Monterey County Water Recycling Projects, there have been no reports of any public health problems connected with the use of recycled water for irrigation of vegetable crops. The state and local public health officials have been involved in monitoring the system. In addition, the Monterey County Environmental Health Department has performed independent tests of water quality for the presence of indicator microorganisms. The results have verified the monitoring results obtained by MRWPCA. Personnel from the Monterey County Environmental Health Department recently participated in a tour of the project with a group of out-of-state visitors and responded to the visitors' questions with positive reports about the safety of recycled water used for irrigation.

Conclusion: The following conclusions are based on the operational record of the Monterey Water Recycling Projects, ongoing monitoring studies, and its predecessor five-year field pilot and demonstration project:

1. Disinfected tertiary recycled water is safe. The water is virtually pathogen-free and safe for direct contact with humans, such as in breathing sprinkler aerosols.
2. Use of recycled water for irrigation of raw-eaten food crops is safe for consumers of raw-eaten food crops thus irrigated.
3. Since use of recycled water for food crop irrigation is demonstrably safe, its use for the less-intimate uses, such as landscape irrigation, is by comparison deemed equally safe.
4. Public and consumer acceptance of food grown with recycled water has not been an issue. Food safety has been scientifically documented and therefore labeling has not been required.
5. Posting of sites with warning signs sends a mixed message to the general public. Posting is required by existing regulations to prevent unauthorized use of recycled water for drinking[11]. Flexibility in the design, wording, and color scheme of signs is feasible and can result in greater public acceptance.

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[11] This requirement is intended to add an additional layer of conservatism to the safe use of recycled water, even though a number of accidental and intentional illegal cross-connections (and the resultant unwary consumption of recycled water) have not been traced to any documented negative outcomes.

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