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Economic Evaluation for Water Recycling In Urban Areas of California

by

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ABSTRACT

Documented uses of recycled water in California go back to the 1890's. Since then, communities throughout the state have developed means to reclaim wastewater and reuse it for beneficial purposes. As the state's population grows and competing demands for water increase, recycled water becomes an important component in the state's water supply resource. In June 2003, California's Recycled Water Task Force estimated that $9 billion to $11 billion in capital investment is required between 2003 and 2030 to add 1.4 to 1.67 million acre-feet of recycled water to the state's water resources. The State's Recycled Water Task Force found that funding and economic issues are two of the six main issues that hinder the increase of recycled water use in the state. Utilities serving communities throughout California will need to perform economic evaluation to determine if they should proceed with making significant capital investments towards recycled water. This paper is intended to be a guide for communities in using Benefit-Cost Analysis for economic evaluation of recycled water projects. Risk Analysis also is discussed. Together the Benefit-Cost Analysis and Risk Analysis provide summary information to support decision-makers. This paper provides a framework for analyzing quantitative and qualitative benefits and costs. Relevant stakeholders' perspectives are also taken into account.

INTRODUCTION

In California's arid climate, with competing demands for scarce water, reuse of wastewater effluent may be a valuable addition to the water resource portfolios of many California communities. To gain broader acceptance of water reuse, the State of California amended its Water Code in 1995 to use the term "recycled water" for "reclaimed water" and "recycling" for "reclamation."[1, 2] The terms "recycled water" and "reclaimed water" are synonymous in this paper, following industry practice and the State of California. In this paper, industry terminology in California is followed. The following definitions apply.

- Reuse of wastewater effluent is synonymous with water reuse.
- Water reuse is the use of treated wastewater for beneficial purposes.[3]
- Water reclamation is the collection and treatment of wastewater effluent.
- "Reclaimed water" or "recycled water" is wastewater treated to a reusable quality for beneficial purposes.

The degree of treatment needed for recycled water depends on the quality of the water required for the beneficial application and public health protection.[4] The California Department of Public Health has established water quality and treatment standards for recycled water uses under Title 22, Chapter 4 of the California Code of Regulations to protect public health.

California has a long history of obtaining beneficial use from wastewater. As early as 1890, wastewater was used for agricultural irrigation. In this same period, the Golden Gate Park in San Francisco was established and initially landscaped with raw wastewater; due to complaints, treatment was added in 1912.[5] Over this century, communities throughout California have developed means to reclaim wastewater and redistribute it for beneficial uses. Wastewater treatment technology has continued to improve along with knowledge of the protection of public health, allowing communities to expand the beneficial uses for reclaimed wastewater. In addition to irrigation application, treatment technology has advanced to allow injection of recycled water into groundwater aquifers for indirect potable water reuse. Despite its long history and the advances in treatment technology, recycled water use in California remains limited from its full potential.

California's current population of 37.8 million is expected to increase to 59.5 million by 2050.[6] Today, 95 percent of California's population lives in urban areas.[7] Though most of the state's population will continue to be in southern California, the Central Valley's San Joaquin County is expected to have the greatest percentage growth (200%) over the next fifty years.[8] Urban growth will encroach into farming areas. With the use of best water management practices, urban net annual water demand is expected

[1] State of California, California Water Code. 2007, Section 13050 Subdivision (n)
[2] Asano, et al., 2007, p. 10.
[3] Ibid, p. 6.
[4] Recycled Water Task Force, 2003, p.2.
[5] Ibid, p. 5.
[6] State of California, 2007.
[7] Landis, 2002.
[8] California Department of Water Resources, 2005, Vol. 1, p. 3-4.

to increase from 6,800,000 acre-feet in 1990 to 10,500,000 acre feet by 2020.[9] Recycling water can help meet future urban water demands while minimizing impacts to agricultural and environmental water demands. By 2030, California may be able to recycle 1.5 million acre feet of water, thereby increasing the availability of freshwater supplies to meet 30 percent to 50 percent of household demands from population growth.[10]

In view of the potential of wastewater reuse as an additional water resource, the State of California's Department of Water Resources formed the Recycled Water Task Force to guide decision-makers, utilities, the public, and water recycling stakeholders in the expansion of recycled water use. The Recycled Water Task Force estimates that $9 billion to $11 billion in recycled water capital investments will be required by year 2030 to add 1.4 to 1.67 million acre-feet per year to the state's water supplies.[11] Utilities and the communities they serve would need to assess if they should invest in costly recycled water projects. Financial analysis assists utilities in determining if they can financially support recycled water projects and their expected funding needs and projected revenues. However, financial analysis alone cannot capture all major benefits and costs of water recycling. Economic evaluation by Benefit-Cost Analysis provides accounting for the broader benefits and costs of recycled water, expanding from the viewpoint of financial analysis. Decision alternatives can then be compared to make the best water resource investment decisions. Using the Benefit-Cost Analysis method, recycled water can be shown to be a worthwhile augmentation to the state's water supply.

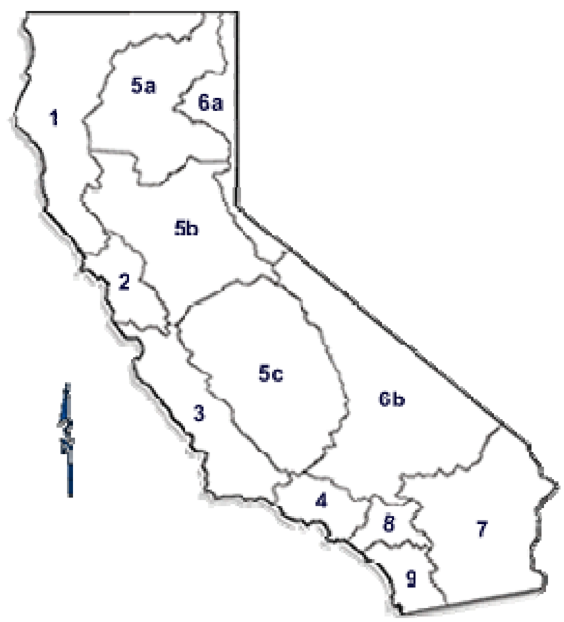
[9] California Department of Water Resources, 1998, ES Chapter 3.
[10] Recycled Water Task Force, 2003, p.5.
[11] Ibid, p. 15.

BACKGROUND

Since the 1890's, California communities have developed means to recycle and reuse water. By 1910, more than 35 communities were irrigating farms with reclaimed wastewater. By 1952, 107 communities were irrigating farms and landscaping with reclaimed wastewater.[12] In 2001, the California State Water Resources Control Board conducted a survey of recycled water use in the state. The Board has divided the State into nine regions, as shown in Figure 1. The results of the survey, shown in Figure 2 and Table 1, indicate that the state is using approximately 525,000 acre-feet of recycled wastewater.[13] Given that California produces approximately 5 million acre-feet per year of treated wastewater effluent, the statewide wastewater reclamation and reuse rate is about ten percent (10%) of the available wastewater effluent.[14] Approximately 29 percent (152,000 acre-feet) of the recycled water is produced and used in Region 4—the Los Angeles region, which has the largest urban population in the state. Approximately 46 percent (241,000 acre-feet) of the recycled water produced in the state is used for agricultural irrigation.

By 2030, the state is estimated to have a population of 46.1 million, who will be producing an estimated 6.5 million acre-feet of treated wastewater effluent per year. The Recycled Water Use Task Force projects up to 2,250 thousand acre-feet of recycled water use in that time period.[15]

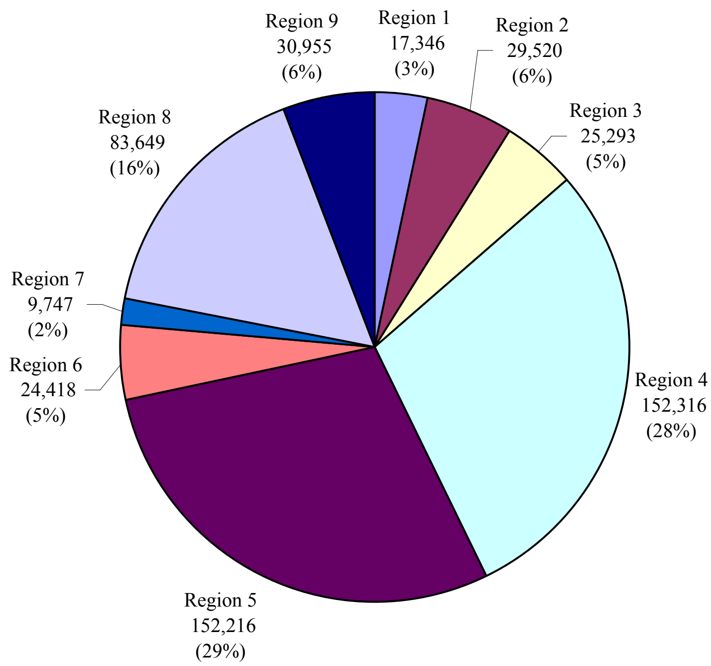
Figure 1. California State Regional Water Control Board Regions
(Courtesy: California State Regional Water Control Board, http://www.swrcb.ca.gov/regions.html.)



No.	Region
1	North Coast
2	San Francisco Bay
3	Central Coast
4	Los Angeles
5A	Central Valley (Redding)
5B	Central Valley (Sacramento)
5C	Central Valley (Fresno)
6	Lahontan
7	Colorado River Basin
8	Santa Ana
9	San Diego

[12] Ibid, p. 5.
[13] California State Regional Water Quality Control Board, 2002.
[14] Recycled Water Task Force, 2003, p. 12.
[15] Ibid, p. 13.

Figure 2. Volume of Recycled Water Use By Region, Acre-Ft (%)



Total Recycled Water Use in California, 2001: 525,460 Acre Feet
(State Water Resources Control Board, 2002)

Table 1. Recycled Water Use in California, 2001
(Courtesy: California State Water Resources Control Board, Office of Water Recycling)

	Volume of Recycled Water Use Within Region, Acre-Feet/Year											
Types of Reuse	**1**	**2**	**3**	**4**	**5A**	**5B**	**5C**	**6**	**7**	**8**	**9**	**Total**
Agricultural Irrigation	12,694	8,318	22,110	3,752	1,314	35,349	110,046	8,588	2,951	30,795	5,033	240,950
Landscape Irrigation	2,675	10,114	3,152	26,229	51	1,431	80	8,418	6,624	28,135	24,191	111,100
Industrial Use	-	4,865	26	22,376	61	264	-	65	-	199	-	27,856
Groundwater Recharge	-	-	-	46,247	-	2,500	-	-	-	-	286	49,033
Seawater Barrier	-	-	-	10,651	-	-	-	-	-	15,000	-	25,651
Recreational Impoundment	-	-	-	24,429	-	-	111	7,347	-	-	1,216	33,103
Wildlife Habitat/Mis.	1,977	6,198	5	6,437	-	1,009	-	-	172	4,361	41	20,200
Geyser/Energy Production	-	-	-	2,198	-	-	-	-	-	-	-	2,198
Other/ Mixed Type	-	25	-	9,997	-	-	-	-	-	5,159	188	15,369
TOTAL	17,346	29,520	25,293	152,316	1,426	40,553	110,237	24,418	9,747	83,649	30,955	525,460

BENEFICIAL USES OF RECYCLED WATER

California's history of beneficial use of reclaimed wastewater commenced with agricultural irrigation. As treatment technology improved, the use of recycled water has expanded to other purposes. As those beneficial applications increased exposure and contact with the public, public health protection becomes a concern. Today, the allowable application for recycled water is limited by the extent of treatment process that wastewater undergoes to become recycled water. Disinfected tertiary treated wastewater effluent, disinfected secondary-2.2 treated wastewater effluent, disinfected secondary-23 treated wastewater effluent, and undisinfected secondary treated wastewater effluent may be reclaimed and applied to beneficial use.[16] The California Department of Public Health (formerly known as the Department of Health Services) has established water quality and treatment standards for recycled water uses under Title 22, Chapter 4 of the California Code of Regulations to protect public health. The reuse applications and level of treatment required was summarized by the WateReuse Association in the table "Recycled Water Uses Allowed in California," included in this paper as Appendix A.[17] The most common uses of recycled water in California are discussed below. In Table 1[18], reuse of urban wastewater is summarized for each California Water Quality Control Board region.

<u>Agricultural Irrigation.</u> Approximately 40 percent of California's applied water use is for agricultural irrigation.[19] Most of that irrigation applied water is lost through evapotranspiration and is not returned into the water system for downstream use.[20] Agricultural irrigation using recycled water is an ideal symbiotic relationship between farmers who need water, and urban communities who must dispose of their wastewater effluent. Wastewater treatment facilities had convenient disposal of their effluent while earning revenue from water that would have been discharged to surface waters.[21] Recycled water also increases crop yields and decreases use of chemical fertilizers.[22] This ideal relationship is illustrated in Table 1, where Region 5C, one of the most agriculturally productive regions in the State, uses the most recycled water for agricultural irrigation. Central Valley farm lands located near wastewater treatment facilities have long taken advantage of this readily-available, usually low-cost water. All regions take advantage of this resource for agricultural irrigation.

The use of recycled water for agricultural irrigation presents some public health concerns for farm workers and produce consumers. The minimum Title 22 treatment requirement for agricultural application is secondary treatment and no disinfection for non-food bearing plants, fodder and fiber crops, and fruit-bearing plants which have no contact with recycled water. Increased treatment is required when edible portions of plants come into direct contact with recycled water.[23]

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[16] California Code of Regulations, Title 22, Division 4, Chapter 3, Article 1, §60301.200, §60301.220, §60301.225, §60301.230.
[17] WateReuse Association, 2002.
[18] California State Water Resources Control Board, 2003.
[19] California Department of Water Resources, 1998, p. 4-3.
[20] California Department of Water Resources, 2005, p. 3-4 to 3-7.
[21] Recycled Water Task Force, 2003, p. 7.
[22] Asano, 1998, p. 30.
[23] Watereuse Association, 2002.

Overall, 46 percent of the recycled water produced in California is used for agricultural irrigation. As communities grow in the future, and more wastewater is produced in urban areas, investment in capital improvements would be required to take reclaimed wastewater from urban areas to agricultural areas for beneficial use.

Landscape Irrigation. In urban areas, landscape irrigation is a significant water demand. Landscape irrigation demands vary by region, depending on the climate and population densities. Like agricultural water consumption, most of landscape water use is consumed through evapotranspiration and not available for downstream use. The Department of Water Resources estimates landscape irrigation applied demands are approximately 3 million acre-feet, or 34 percent of the state's urban water use.[24] The use of recycled water could reduce freshwater demand for landscape irrigation, particularly in growing communities where recycled water distribution systems are less expensive to construct. Recycled water use help satisfy household water demands while maintaining desired outdoor aesthetics. This recycled water application is another ideal relationship between communities with landscape irrigation demands and wastewater treatment plants that need to discharge their effluent in an environmentally responsible manner. Most often the wastewater treatment plant is in or adjacent to the community that it serves.

Recycled water is most commonly applied in golf courses, schools, parks, and other landscaped areas in the urban setting. This use presents health concerns to the general public, who has greater probability of exposure and contact with recycled water. The minimum Title 22 treatment requirement for recycled water applied in low probability exposure areas, such as median and streetscapes and cemeteries, is secondary treatment with disinfection.[25] Higher treatment standards are required for application in schools, parks, and golf courses.

Overall, 21 percent of recycled water produced in California is used for landscape irrigation. All regions take advantage of this resource for landscape irrigation. As communities grow, household water demands increase and more wastewater is produced in urban areas, capital improvements would be required to take reclaimed wastewater from treatment plants and distribute it to uses within the community. In some cases, this investment may be more costly than investing in infrastructure to export recycled water to agricultural areas or other recycled water uses.

Combined together, 67 percent of recycled water use in California is for irrigation application. The seasonality of irrigation compared to the relatively constant availability of wastewater results in recycled water shortage during the dry season and overage during the wet season. During the dry season, communities need to augment the shortage of recycled water with freshwater or potable water augments. During the wet season, communities are still left with wastewater effluent disposal issues. Recycled water storage presents a solution that addresses both dry and wet season issues; however, this solution may be limited or difficult to implement. Other innovative uses of recycled water are required. As shown below, California communities are striving to meet this challenge.

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[24] California Department of Water Resources, 1998, p. 6-6 to 6-10.
[25] WateReuse Association, 2002.

<u>Groundwater Recharge and Seawater Barrier.</u> Currently, 30 percent of California's urban and agricultural water demands are satisfied by groundwater extraction.[26] Historical groundwater pumping to meet water demands has led to problems of overdrafts and increased groundwater salt concentrations in some places. Along coastal communities, seawater has intruded into communities' fresh groundwater supplies. Recycled water replenishment of groundwater aquifers has been practiced in California since 1962 via pond percolation. Since the 1970's, direct injection of advanced treated recycled water into aquifers also has been used.[27] Using recycled water to replenish aquifers satisfies several objectives. Reclaiming wastewater reduces loss of freshwater from the region. Using recycled water for groundwater replenishment slows and reduces groundwater overdraft, protects coastal groundwater aquifers from seawater intrusion, and augments water supplies.[28]

Because most aquifers are the source of potable water supply for communities, the injection of recycled water into these aquifers is indirect potable water reuse. The Department of Health Services and the Regional Water Quality Control Board reviews and permits these applications on a case-by-case basis, and requires advanced treatment processes.[29]

Overall, 14 percent of current recycled water application is used for groundwater replenishment and seawater barriers. Five of the nine regions in California—most in the coastal regions of southern California—use recycled water for this application. Public health concerns and stringent permitting requirements limit aquifer recharge with recycled water. Treatment, infrastructure, and operating costs also limit this application. The advantages to using recycled water for aquifer recharge should be included in the economic feasibility study. The cost of groundwater basin storage and distribution may be less than the capital and operating cost of surface storage and pipeline distribution. Also, surface storage may not be environmentally feasible and are subject to evaporation loss and aesthetic water quality problems.[30] As technology improves further and public acceptance and knowledge increase, recycled water use for groundwater replenishment may come closer in achieving its potential.

<u>Other Uses.</u> California has been innovative in its use of recycled water. Other current beneficial uses of recycled water include recreational impoundments, wildlife habitat, and industrial uses. Recycled water is impounded to create golf-course water hazards, and fishing, boating, and other non-body contact recreational water areas. Recycled water also is used to create wetland habitat for wildlife. Its role in industry includes cooling make-up water in electric power plants, oil refining, and other chemical and metal plants.[31] Other small scale uses include being a secondary source of water for toilet flushing. Approximately 19 percent of current recycled water produced is used in these various applications. Some of these other uses require additional water. Concerns related to costs, public health, water quality to preserve industrial equipment, and cross-connections with domestic water are limiting factors in these uses.

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[26] California Department of Water Resources, 1998, p. 6-48.
[27] Recycled Water Task Force, 2003, p. 12.
[28] Asano, 1998, p.40.
[29] WateReuse Association, 2002.
[30] Asano, 1998, p. 40.
[31] Ibid, p. 35-38.

MOTIVATIONS FOR RECYCLED WATER USE

Many communities are turning to wastewater reclamation and reuse to solve multiple issues within their growing communities. Water recycling provides an alternative wastewater effluent disposal method and an alternative source for water supply. It also increases water supply reliability during droughts. A few examples of community motivation for recycled water use are discussed briefly below.

Dublin San Ramon Services District/East Bay Municipal Utilities District Recycled Water Authority. This authority was formed by both Dublin San Ramon Services District (DSRSD) and East Bay Municipal Utilities District (EBMUD) to provide water for the growing cities and counties within their service area. DSRSD's service area alone is expected to triple by 2015. This expansion demanded greater water capacity and wastewater treatment and export capacity than DSRSD was able to provide at that time. Approximately 10 years of negotiations yielded a water transfer that would satisfy most, but not all of the additional water demand from the area's 2015 ultimate growth projections. Additionally, the DSRSD has limited wastewater effluent disposal capacity. DSRSD shares a 16-mile wastewater effluent export pipeline to San Francisco Bay with nearby cities. To accommodate the growing communities in the area, a parallel export pipeline is required. The installation of the parallel pipeline by DSRSD or by the nearby cities alone is cost prohibitive. Negotiations for cost sharing between the cities and DSRSD were deadlocked. Given the urgency of obtaining additional wastewater export capacity and the looming need to augment its water supply, DSRSD partnered with an adjacent water district, EBMUD, in 1995, to reclaim wastewater and distribute recycled water to their customers for landscape irrigation. The first phase of the program was implemented in Fall 2005 to serve approximately 3.3 thousand acre-feet of water per year. The program will ultimately treat and distribute approximately 21.8 thousand acre-feet per year of recycled water in the East Bay.[32]

South Bay Water Recycling Program. In 1991, the San Francisco Regional Water Quality Control Board ordered the City of San Jose to cap its discharge to the San Francisco Bay from 135 million gallons a day to 120 million gallons a day.[33, 34] The freshwater discharge in the saltwater marine ecology of the South San Francisco Bay has been detrimental to two endangered marine species, the California Clapper Rail and Salt Marsh Harvest Mouse.[35] If the discharge is not reduced, a ban on new sewer connections would be imposed for the eight cities served by the City's wastewater treatment plant. New construction in those cities would be halted. This ban would have damaged the economy of the region. The City of San José, City of Milpitas, City of Santa Clara, West Valley Sanitation District, Burbank Sanitary District, Cupertino Sanitary District, Sunol Sanitary District, County Sanitation District No. 2-3, San Jose Water Company, Great Oaks Water Company, Santa Clara Valley Water District, and United States Bureau of Reclamation worked in partnership to reclaim wastewater from the San Jose/Santa Clara

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[32] DERWA, www.derwa.org, 2008.
[33] Sweeney, 2002.
[34] Wong, 1999, p. 133.
[35] Alameda County Water District, 2000, Chapter 4.

Water Pollution Control Plant and distribute recycled water to their customers throughout the South Bay. This consortium of agencies funded the installation of a network of distribution system that now delivers recycled water to their areas of jurisdiction. The program currently delivers 5.9 thousand acre-feet per year of recycled water to South Bay users, mostly for landscape irrigation and industrial use.[36] Ultimately, the program will expand to reclaim more than 40 thousand acre-feet per year of wastewater for landscape irrigation and industrial use throughout the South Bay and its neighboring communities.[37]

City of Santa Rosa Incremental Recycled Water Program. The Santa Rosa Subregional Water Reclamation System has operated for more than 20 years. The City's current National Pollutant Discharge Elimination System (NPDES) permit allows treated wastewater effluent discharge into the adjacent Russian River and tributaries only between October 1 and May 14.[38] Expansion of the subregional water reclamation system is needed to accommodate the additional 1.9 billion gallons of wastewater flow projected from the surrounding communities' expected 20-year growth.[39] The City also wishes to maximize recycled water reuse opportunities to increase freshwater availability for potable uses.[40] The City must manage 31 thousand acre-feet per year of average dry weather wastewater flow by year 2020.[41] The program's Recycled Water Master Plan proposes increased reuse in agricultural and urban applications and expansion of service to recharge of geothermal geysers in the surrounding area. The program's Environmental Impact Report was approved in 2003. The City is currently evaluating recycled water project implementation priorities.

SOLUTION TO MULTIPLE REGIONAL WATER MANAGEMENT ISSUES

The projects above illustrate that recycled water projects can be successful regionally, where multiple problems are solved cooperatively among multiple stakeholders. At the outset, wastewater reuse and recycling address many communities' wastewater effluent disposal issues. Treated wastewater effluent discharged into surface waters has harmed the environment by altering water quality. In the City of San Jose, the habitat of endangered species is disturbed. Often, these surface waters are a potable water source for downstream communities, requiring public health protection. Wastewater utilities are stakeholders whose interests lie in meeting geographical, physical, and/or regulatory limitations on their effluent discharge. Water recycling can diversify their portfolio of wastewater effluent management.

Much of the literature produced by the State of California pertaining to recycled water discusses increasing population, growing communities and their associated water demands, the limited California water supply, and the pressures of demands for urban use, agricultural use and environmental use. Many communities are experiencing these pressures and have turned to wastewater reclamation and reuse to manage their water resources and to ensure sustainability while developing their urban areas.

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[36] California State Regional Water Quality Control Board, 2002.
[37] City of San Jose, 2005.
[38] City of Santa Rosa, 2004, p. ES-7.
[39] City of Santa Rosa, 2003.
[40] City of Santa Rosa, 2004, p. ES-2 to ES-5.
[41] Ibid, p. ES-9.

Reclaiming and locally reusing wastewater effluent that is an indirect water supply for a downstream user merely shifts benefits to the upstream community, from the downstream community. Recycling water contributes most to the California water budget when used to recover and use water that would have been directly discharged into the ocean or lost through evapotranspiration. Recycling water can help mitigate increased demands from Northern California sources, the Bay Delta, and the California Water Project, while minimizing water lost to the ocean. Successful water reclamation projects along the California coastal and agricultural communities contribute to the management of the State's water resources. Mitigation, however, is required to minimize recycled water's impacts to water quality in groundwater basins in agricultural communities.

The public most readily accepts the application of recycled water when there is minimal direct exposure or contact. Recycled water is deemed acceptable for irrigation, and much less so for indirect potable reuse. Proponents of recycled water have worked with the California Water Quality Control Boards and the Department of Health Service to develop and distribute Title 22 requirements in the California Code of Regulations. Recycled water quality requirements have significantly developed along with technology and public health knowledge since initial distribution of recycled water in the farming fields California in the 1890's.

Given the potential of recycled water and the needs of expanding communities in California, communities need to sensibly analyze the feasibility and value of establishing a recycled water enterprise. Recycled water treatment and distribution infrastructure require significant financial investments. In recent years, advances in treatment technology have reduced capital and operating costs. Meanwhile, demands on limited traditional sources of freshwater continue to increase, along with its financial and environmental costs. These combined changes bring costs of water recycling to levels more competitive with obtaining and treating additional freshwater. A feasibility study and its accompanying economic evaluation will provide communities the ability to make informed decisions in establishing a recycled water enterprise and pursuing a recycled water project.

ECONOMIC EVALUATION BY BENEFIT-COST ANALYSIS

PRELIMINARY PLANNING FOR RECYCLED WATER

To assess if, when, and at what scope a recycled water enterprise should be pursued, a feasibility study is typically conducted. A feasibility study is part of preliminary planning that identifies a community's issues and assesses if a project is a viable solution to those issues. Economic evaluation is a major part of a feasibility study and allows the community to assess how it can best benefit from its investments over a determined time horizon of planning. Public agencies typically use a time horizon of planning of 20 years; alternatively, the time horizon of planning may be the projected year of ultimate buildout of a community. Time horizon of planning needs to be defined so that options—baseline, the proposed project, and alternative projects—can be compared over the same time period for effective comparison. For recycled water project planning, the feasibility study provides an opportunity to present multiple objectives for reclaiming wastewater effluent for reuse.

The feasibility study for a recycled water project is often spearheaded by a community's wastewater utility, which has a strong interest in solving wastewater effluent disposal issues. However, as recycled water provides solution to water utilities' needs for sustainable water supplies, water utilities often become partners in the effort. For example, DSRSD and EBMUD partnered to form DSRSD/EBMUD Recycled Water Authority (DERWA) so DSRSD may reduce its wastewater effluent discharge and EBMUD could provide additional water supply to its service area. Each utility and community's situation is unique, and feasibility studies for their projects encompass a variety of subjects. Typically, a recycled water feasibility study includes the components below.[42]

<u>Objective Identification.</u> The initial section of a feasibility study identifies and develops purposes and objectives over a determined time horizon of planning. Note that water recycling is not the objective, but is a means to address more fundamental objectives. Water recycling provides a potential solution to multiple water and wastewater issues and is often most cost effective when used to meet several objectives.

<u>Alternative Solutions Identification.</u> Once the objectives are identified, practical alternative solutions, in addition to water recycling, are identified. A no-action solution is typically included as a control alternative for comparison.

<u>Service Area Identification.</u> The study area potentially served with recycled water is identified in this component. Usually, the service area is defined as the area that can be feasibly served from the source of the recycled water.[43] A partnership between water and wastewater utilities may require that a service area be created across jurisdictional lines of the participating utilities. Also, a service area may be created to achieve an economy of scale to minimize or reduce costs.

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[42] Asano, 1998, p. 57-111.
[43] Ibid, p. 63.

Market Assessment. The success of a recycled water enterprise depends on public support and the willingness of water customers to use recycled water. In conjunction with identifying a possible recycled water service area, potential customers who are capable and willing to use recycled water need to be identified. Their potential recycled water application is assessed and their demands are estimated. The market may be limited by the quantity of wastewater effluent produced and reclaimed.

Environmental Impacts. Use of recycled water may result in positive and negative effects to the local and regional environment. For example, the City of Santa Rosa plans to use recycled water to allow the surrounding communities to sustain planned growth, while minimizing wastewater effluent discharge into the Russian River. Significant regional and local environmental impacts, beneficial or not, need to be recognized to present a holistic feasibility analysis. Detailed studies may be performed should the community proceed with its project.

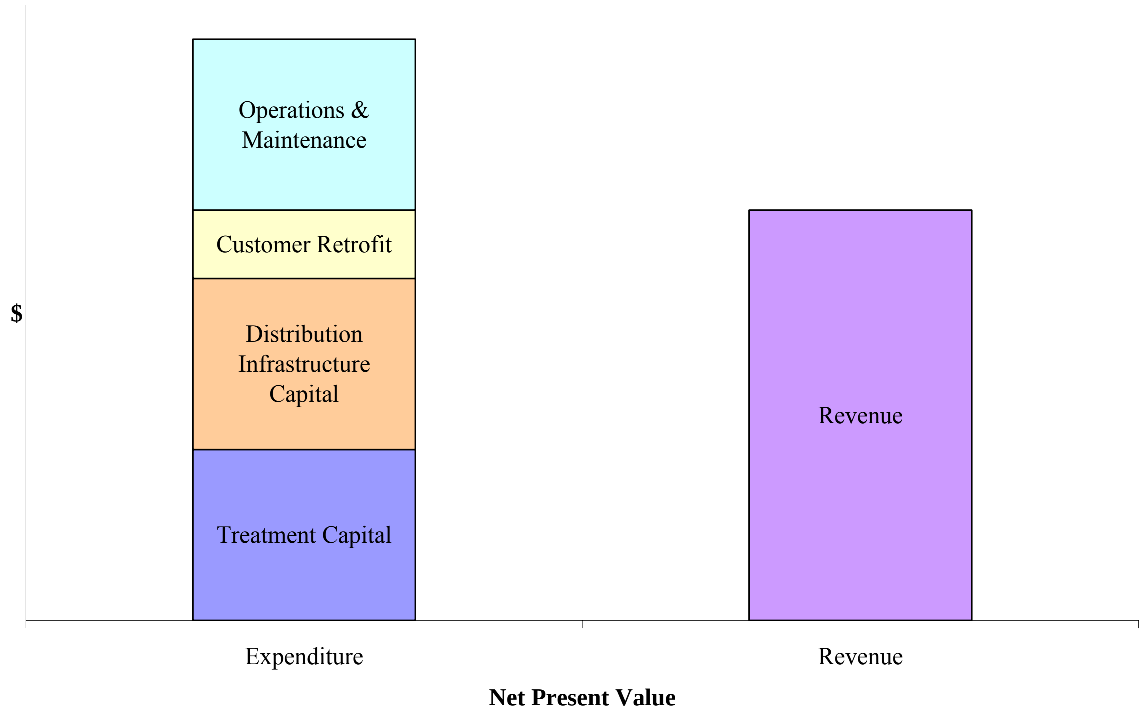
Treatment and Distribution Options. Given Title 22 requirements and the market's expected recycled water application, recycled water treatment options need to be identified; the recycled water quality produced should match its intended uses. As treatment technology advances and cost is reduced, different treatment alternatives should be considered. Additionally, recycled water distribution system alignment options should be identified for delivering recycled water to customers. The ideal alignment minimizes effects on existing community infrastructure, minimizes recycled water pipeline infrastructure installation, and allows a maximum number of customers to connect to the recycled water system.

Economic Evaluation. Using the above components, an economic evaluation can be performed to assess if wastewater reclamation and recycling is feasible for the objectives identified. Economic evaluation expands the assessment of proposed solutions beyond financial impacts. The Benefit-Cost Analysis method is a generally accepted economic evaluation method in the water resource industry. Benefit-Cost Analysis allows evaluation of financial cost and revenues to install and operate recycled water facilities, and evaluation of other monetary and non-monetary benefits and costs to communities and the surrounding region, spread over a determined time horizon of planning.

FINANCIAL ANALYSIS AND ECONOMIC EVALUATION

Both financial analysis and economic evaluation are decision aids that are used to assess if an investment will provide satisfactory returns. Financial analysis compares cash flow expenditures and revenues of an investment; if expected revenues exceed expenditures over the time interval of the assessment, the entity can feasibly proceed with spending money on that investment. Economic evaluation includes non-monetary value of recycled water to utilities and the communities they serve. The analysis incorporates financial, environmental, and social costs and benefits—factors that affect and concern the general public—over an assessment's time interval.

Figure 3. Financial Analysis Illustration



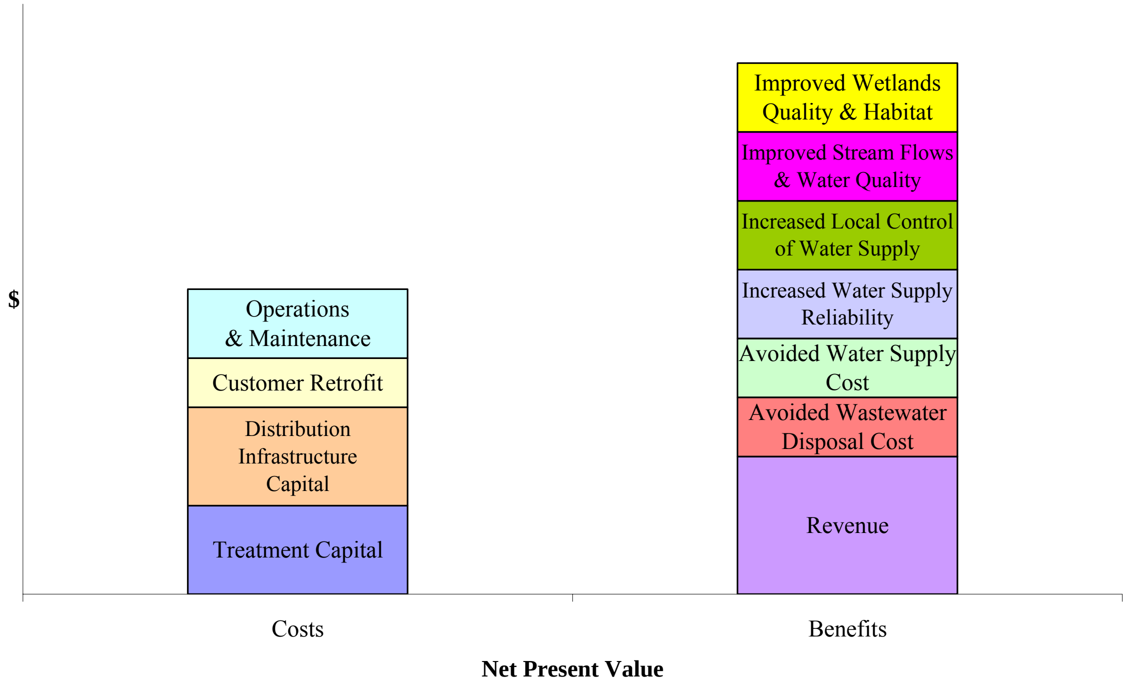
For most private entities, the financial analysis method provides an effective evaluation of their investment strategy. Typically, private entities' main objective is to stay in business and obtain profit. Investments that yield the greatest expected net positive cash flow would be preferred.

When a public agency or utility performs a financial analysis for a recycled water project, the analysis would be based on monetary cost for the installation, operation, and maintenance of its treatment and distribution infrastructure, and of revenues collected from customers along with the timing of these costs and revenues. This cash flow comparison is shown in Figure 3.[44] The result is most often unfavorable for recycled water projects.

However, utilities directly serve communities and are part of the public sector; even privately-owned utilities are regulated by the public sector such that they are very much like publicly-owned utilities. In the public sector, the objectives of decision making is directed towards the well-being and improvement of the quality of life—the welfare—of society, the general public. Benefits and costs that concern the public go beyond monetary net revenues to the sponsoring agency, and includes social and environmental factors. The analysis of benefits and cost of utility projects to society is an application of welfare economics. In reviewing the distribution of welfare (benefits) and allocation of costs in society, value judgment is used to assess the relative desirability of change in the state of society.[45] This analysis uses a decision criterion known as Potential Pareto Superiority, which identifies a project as "superior if those who gain from the

[44] Raucher, p. 7.
[45] Sassone and Schaffer, p. 6.

Figure 4. Economic Analysis Illustration



project could compensate those who lose so that none would be worse off with the project."[46] Economic evaluation is the method of analysis that befits the objectives of the public sector and the public at large in decision making. For recycled water projects by public agencies, the benefits and costs comparison used in economic evaluation is illustrated in Figure 4.[47] By including benefits and costs beyond cash flow, analysis results may be favorable for recycled water projects.

METHODS OF ECONOMIC EVALUATION

Two evaluation methods are most often used for public projects: Benefit-Cost Analysis and Cost-Effectiveness Analysis. Benefit-Cost Analysis is used in formal economic evaluation, where alternatives have varying financial, environmental, and social benefits and costs. Cost-Effectiveness Analysis is used when "it is unnecessary or impractical to consider the dollar value of the benefits provided by the alternatives under consideration."[48] For example, this analysis can be used when each alternative's benefits are the same, but dollar values cannot be determined. Cost-effectiveness is less comprehensive and used less often than Benefit-Cost Analysis.

In 1844, Jules Dupuit, a French engineer, presented the first literature on Benefit-Cost Analysis in his essay, "On the Measurement of the Utility of Public Works."[49] Dupuit directly contributed to the concept of net social benefit, which is the basis of

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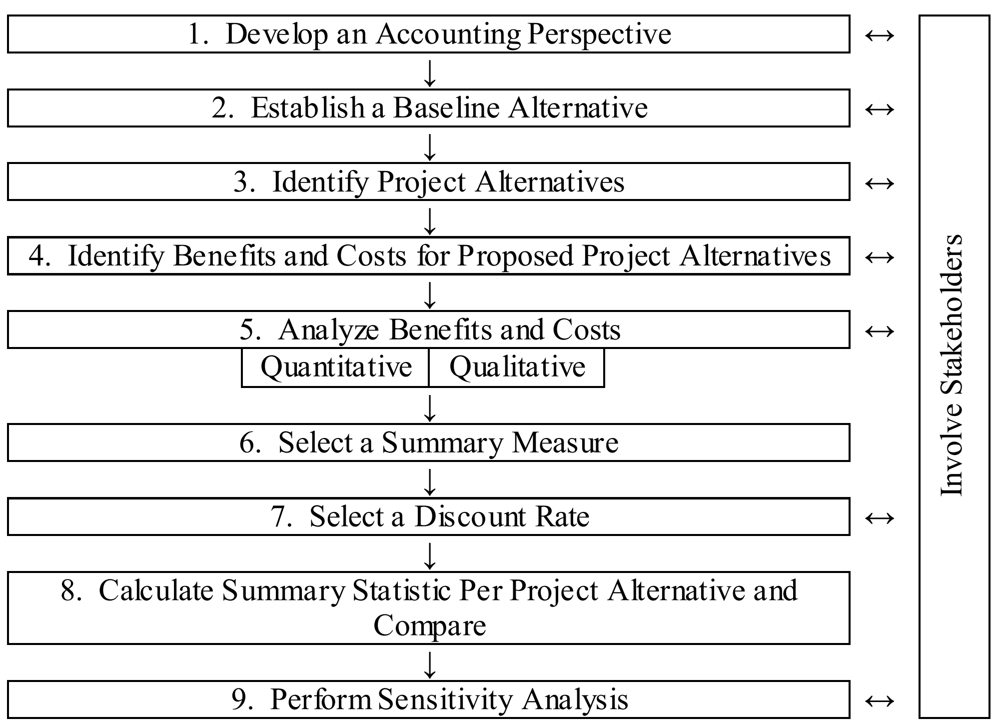
[46] Ibid, p. 12.
[47] Raucher, p. 8.
[48] US Office of Management and Budget, Section 5b.
[49] Sassone and Schaffer, p. 3.

Benefit-Cost Analysis. This concept was first applied by the federal government in 1936 with the United States Flood Control Act, where Congress declared federal projects' social benefits should exceed costs.[50] Over time, Benefit-Cost Analysis has evolved to become the generally accepted means to evaluate projects proposed by the federal government and public agencies. This analytical method is recognized to improve efficiency for society, as it "maximizes the total net benefits available to society."[51] An effective Benefit-Cost Analysis also recognizes and tracks the distribution of benefits and costs amongst various segments of society. Thereby, Benefit-Cost Analysis provides an avenue for evaluating the social equity of a project. Because this analytical method satisfies public policy direction to improve the welfare of society by maximizing net social benefits, and because it provides a means to improve social equity, Benefit-Cost Analysis is often required for public agencies' projects to obtain grant funding from the state or the federal government.

FRAMEWORK FOR PERFORMING BENEFIT-COST ANALYSIS

The series of steps outlined in this section provides a guide to performing Benefit-Cost Analysis for a recycled water project and alternative projects. To ensure public support and success of the project selected for implementation, strategic outreach to stakeholders is recommended at each step of the process, from preliminary planning to customer connection.[52] Stakeholders may be individuals, groups, or organizations with

Figure 5. Steps in Benefits-Cost Analysis *(Raucher, 2006)*



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[50] Ibid, p. 4.
[51] National Center for Environmental Decision-Making Research (NCEDR), Overview
[52] Raucher, p. 12.

real or perceived interest in the feasibility study and economic evaluation. Stakeholders may consist of:[53]

- the general public, the rate payers in the responsible agency's service area;
- elected officials, who set direction and policies for communities;
- internal public agency or utility staff, whose responsibility is to find solutions to issues facing the related and involved agencies. These staff include the agency or utility managers, engineers, facilities operators, and planners;
- the business community, who are interested in the economic vitality and land development of the community;
- other government agencies, which have overlapping jurisdictions or regulatory and permitting responsibilities;
- recycled water customers, who will be the end users of the product.

Inputs from stakeholders help identify a broader range of benefits and costs for evaluation. The following steps provide a framework for Benefit-Cost Analysis. The steps are summarized in Figure 5.[54]

Step 1: Develop an Accounting Perspective.

Prior to delving into calculating benefits and costs of a project, an accounting perspective must be selected over a determined time horizon of planning. Accounting perspective is the point of view that one must take to perform the accounting analysis. One's accounting perspective is influenced by the interest and objectives of the entity it serves and the time horizon for planning. Benefits and costs are relative to the developed accounting perspective. Samples of influences to accounting perspectives regarding water reuse are shown on Table 2.

A recycled water project provides benefits and costs for the state, a region or area around and within a community, and even individuals within the community. To identify and estimate the value of those benefits and costs over a determined time horizon for planning for the entire state, or for each individual within a community, can be time-consuming and costly. Each level of public agency, from state or county or region or city, has its own perspective on benefits and costs based on its interests. Each agency would be more concerned about the benefits acquired and costs incurred by its own constituents.[55] For decision-makers, the natural inclination is to maximize benefits to the public they serve while minimizing costs.

Developing an economic perspective to achieve a reasonable economy of scale over a determined time horizon for planning for communities is necessary for a successful recycled water program. Benefits are often far-reaching and external to any one community for recycled water projects. For example, increased water supply and improved wetland habitat quality are benefits desired by regional residents, and state residents overall. However, costs may be borne by the smaller scale communities, who would need to construct treatment plants and distribution systems in their areas. Recycled water projects at regional levels, which involve wastewater utilities, water utilities, and more than one city, are successfully implemented as multiple objectives are

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[53] Humphreys, p. 9.
[54] Raucher, p. 19.
[55] Howe, p. 10.

Table 2. Samples of Influences to Accounting Perspective

Group	Interest and Objectives
State Water Resource Agency	Interest: Manage statewide water resources; manage water quality statewide; manage water distribution to regional areas. Water reuse may be beneficial as an addition to its statewide water resource portfolio. Water reuse may be costly since its application may be an issue in statewide water quality management.
Regional Water Resource Agency	Interest: Manage regional water resources; manage water quality regionally; deliver water to its region. Water reuse may be beneficial as an addition to its regional water resource portfolio and provides local control. Water reuse may be costly since its application may be an issue in regional water quality management.
City	Interest: Maintain or improve quality of life within its boundary; manage economic sustainability; manage development growth. Water reuse may be beneficial in augmenting potable water to sustain water needs of current or projected constituents. Water reuse may be costly since it requires significant funding; the installation of facilities may be disruptive to its constituents.
Special Interest Groups	*Perspectives vary depending on focus. Examples listed below.*
Environmental Protection Group	Interest: Preserve or improve recreational areas or undeveloped spaces. Water reuse may be beneficial to maintaining wildlife habitats. Vater reuse may be costly as it supports land developments that encroach into wildlife habitat.
Anti-growth Group	Interest: Preserve existing quality of life. Water reuse may be beneficial as it provides sustainable water supply to the community. Water reuse may be costly as it provides additional water that supports future developments in surrounding cities, thereby deteriorating current quality of life.
Commerce Groups	Interest: Manage financial investments for profit. Water reuse is beneficial as it provides additional resource to support economic growth or development. Water reuse is costly as it requires financial investment for capital projects.
Individual	Interest: Preserve or improve own quality of life. Water reuse may be beneficial as it may induce economic growth (job) and land development growth (new homes, increased property value). Water reuse may be costly as it presents risks in public health.

satisfied, while benefits are captured and costs are shared. Wastewater utilities' effluent disposal issues and water utilities' need to develop and/or maintain sustainable water supplies are jointly addressed.

In developing an accounting perspective for the Benefit-Cost Analysis, stakeholder's input is necessary as decision-makers and their constituents have interest in the future and the welfare of wider areas. In the growing communities of California, the distribution of benefits and costs to existing and future population of communities need to be addressed. Stakeholders have varying viewpoints on these issues. The analyst and the decision makers, as stakeholders, each have their own perspective. The analyst and the decision-makers need to take the collection of stakeholders' viewpoints into consideration in selecting an accounting perspective.

Step 2: Establish a Baseline Alternative.

Water recycling is often a means to achieve multiple objectives regarding a community's water and wastewater problems. However, alternative solutions are also available to a community. To establish appropriate context to compare water recycling and other practical alternative solutions, outcomes associated with a no-action solution need to be defined and used as a baseline alternative. "The baseline is the mark against which changes resulting from the project alternative(s) are measured."[56] The baseline should be defined to articulate the solution objectives and the roles of water recycling and other project alternatives over a determined time horizon of planning. The baseline is not necessarily the current situation, but is rather a view of the long-term future with no action. In assessing recycled water projects, baseline development involves looking at projected water supply and demands with a long-range water resources portfolio without water reuse.[57] Conducting proper evaluation requires comparison of the scale and timing of baseline impacts to those of water recycling and other alternatives. An accounting perspective and the baseline place each management alternative in a context and relative benefits and costs can be established.

Establishing a baseline alternative requires dialogue with relevant stakeholders. Core assumptions regarding baseline and projected outcomes, such as water demand projections and size and pace of population growth, should be discussed with stakeholders. When relevant stakeholders concur with core assumptions and basis of the analysis, the outcome of the analysis is likely to be less controversial. Stakeholders have a greater understanding of the broader problems and situation.

Step 3: Identify Project Alternatives.

In the first phase of the feasibility analysis, the water and wastewater problems of a community (or communities, or region) over a determined time horizon of planning are identified and objectives are developed. In addition to water recycling and the baseline alternative, other alternatives need to be identified to address these objectives. The lifetime of the projects over the time horizon of planning must be identified. Benefit-cost analysis requires that the major benefits and costs of each alternative and each alternatives lifetime over a determined time horizon of planning be taken into account. Other management alternatives may include:

- limiting of regional growth to a level that can be sustained by existing water supply capacity and/or existing wastewater disposal capacity, or
- other wastewater disposal options, such advanced treatment facilities that would treat effluent to a level that would allow discharge into surface water, or expansion of wastewater export capacity, and,
- other water supply options, such as water conservation, desalination, importing water from other regions.
- different water reuse options. For example, limiting the scope of treatment level, capacity, or customers served with recycled water; or groundwater injection for indirect potable water supply.

[56] Raucher, p. 19.
[57] Ibid, p. 22-23.

Evaluation should include alternatives that are most relevant to the objectives identified for the community (or communities, or region).

During the economic evaluation phase, analysis should be limited to projects that are technically, politically, and legally possible for practical purposes.[58] For example, additional water supply from a nearby surface water supply that is restricted because it is inhabited by wildlife protected by the Endangered Species Act probably would not be a practical alternative. Discussions with relevant stakeholders would provide information on the community's values and the options that are likely to be politically acceptable.

Step 4: Identify Benefits and Costs for Proposed Project and Alternatives.

Once the recycled water project, the baseline, and the project alternatives are identified, the range of major benefits and costs related to each alternative should be identified over a determined time horizon of planning. The range of benefits and costs identified can include those that go beyond the community, the regional area, and beyond.[59] The extent of the range is influenced by the accounting perspective established in the first step of Benefit-Cost Analysis. Again, discussion with relevant stakeholders will influence the range of benefits and costs identified.

Benefit and cost impacts for each project alternative may be divided into five categories: financial, environmental, recreational, public health, and socio-economic equity considerations.[60] For any recycled water project, the WateReuse Association, a national organization that highlights water recycling and promotes the beneficial and efficient use of water resources, recommends that economic valuation of recycled water include (1) the cost of producing and conveying recycled water versus the cost of other new water supply options, (2) reduced or delayed infrastructure costs, (3) improved reliability of supply, and (4) environmental benefits.[61]

- Financial impacts include the facilities capital costs, operational and maintenance costs and revenues collected for obtaining additional water supply capacity and wastewater disposal capacity. When considering the recycled water project alternative, alternative water supply or wastewater discharge costs may be avoided as compared to the baseline. For example, expansion capital costs for transporting and treatment of additional water supply and/or treatment and disposal of wastewater effluent should be taken into consideration. Avoided costs or delayed costs should be included in the itemization of benefits for a recycled water project.
- Environmental benefits include surface water or groundwater quality protection and wildlife habitat maintenance, restoration or enhancement. For some alternatives, costs may include surface water or groundwater quality and quantity depletion and wildlife habitat reduction.
- Recreational benefits and costs include changes in recreational opportunities available to people in the communities and the region. For example, water

[58] Ibid, p. 24.
[59] Ibid, p. 20.
[60] Ibid, p. 24-25.
[61] WateReuse Association, September 1999.

recycling may enable a community to develop sports fields or to enhance a nearby watershed.

- Public health benefits and costs include changes in risks of illness or death from changes in the water quality compared with the baseline. For example, an alternative project's treatment process may increase or decrease the probability of public exposure to chemical contaminants, treatment by-products, or microbial agents.
- Socio-economic equity considerations include the distribution of the benefits and costs of a project alternative to sections of the community. The availability of access to resources and aesthetics provided by a project alternative need to be identified, along with the likely aided and harmed parties. For example, the increased water supply and wastewater disposal capacity of a project alternative may contribute to a community's economic sustainability and growth; however, costs associated with growth (such as traffic) must also be considered. Once these effects are identified, the utility may suggest appropriate mitigation measures.[62]

For each of the above categories, assumptions must be made to analyze and quantify the benefits and costs in monetary terms, when possible. Assumptions must be documented and the uncertainties that those assumptions bring must be assessed. In the next steps discussed below, assumptions and uncertainties must be considered.

Step 5. Analyze Project Benefits and Costs.

Once the range of major benefits and costs of the recycled water project, the baseline, and the project alternatives are identified, each option's effects on the community should be assessed. These impacts need to be analyzed quantitatively and qualitatively. The lifetime of each of the project alternatives over the time horizon of planning must also need to be estimated.

Ideally, benefits and costs should be quantified in monetary terms. Direct benefits and costs, such as treatment and distribution capital costs, operation and maintenance costs, and revenue projections can be estimated based on similar projects that have been constructed and placed into operation in California, and throughout the country. In addition to literature, various resource agencies maintain databases that can assist in deriving values for indirect benefits and costs in the areas of recreation, environment, cultural and aesthetics, and even water supply reliability.[63] These agencies include:

- the Department of Agricultural and Resource Economics of University of California, Davis, which maintains its "Beneficial Use Values Database."[64]
- US Environmental Protection Agency, which maintains its "Environmental Economics Reports Inventory."[65]
- Environment Canada, which maintains its "Environmental Valuation Resource Inventory."[66]

[62] Raucher, p. 24-25.
[63] Ibid, p. 37.
[64] Lew, et. al., 2007.
[65] US EPA, 2007.
[66] Environment Canada, 2007.

- US Department of Agriculture, Forest Service, which published the **Benefit Transfer of Outdoor Recreation Use Values**.[67]

Other benefits and costs, which are usually indirect, are difficult to quantify. These impacts are often relevant to stakeholders and should be included in the analysis. These impacts, and their associated assumptions and uncertainties, should be noted and their importance and value to the community (or communities or region) should be described in detail.[68] The measure of their value and importance is discussed in the next step.

Step 6: Select a Summary Measure.

Comparison of a recycled water project, the baseline, and other project alternatives, requires a quantitative summary measure. The summary measure allows decision-makers to compare project alternatives in terms of overall economic desirability. It presents an objective decision criterion that decision-makers can use when considering which alternative to pursue.

Quantitative Measure. In the previous step, the benefits and costs of the baseline, the proposed project and its alternatives are estimated and their values are quantified when possible. This step and the next step below occur concurrently. The benefits and costs of the baseline, the proposed project, and the project alternatives extend into the future and the value of money over time should be taken into account. Time influences the value of money invested in a specific project since this investment foregoes other choices.[69] To effectively compare summary measures of the baseline, the proposed project and its alternatives, each of their summary measures needs to be adjusted to a common timeline and discount rate.

For most analyses, finding the net values of the baseline, the proposed project, and its alternatives provides a satisfactory summary measure and decision criterion. The net value of a project (NV) is the sum of project benefits (B) less the sum of project costs (C), NV = $\sum$ B - $\sum$ C. Once a discount rate is selected, the summary measures of the baseline, the proposed project, and the project alternatives can be adjusted to a common time, which is typically the present time, for effective comparison. The present value of a benefit or cost is calculated using the following equation:[70]

$$PV = FV\,(1 + i)^{-t}$$

where PV is present value of a benefit or cost, FV is future value of a benefit or cost, i is the annual discount rate, and t is the number of years. The net present value (NPV) of each of the baseline, the proposed project, and the project alternatives is the sum of the present values of the benefits over time less the sum of the present values of the costs over time:

$$NPV = \sum_{t=0}^{\infty}\left(\sum_{j=1}^{n} B_{jt} - \sum_{k=1}^{m} C_{kt}\right)(1+i)^{-t}$$

[67] Rosenberger, et. al, 2001
[68] Raucher, p. 31.
[69] NCEDR, Module 2, Section 1
[70] Asano, 1998, p. 85.

where *j* represents benefits 1 to *n* at each time period, and *k* represents cost 1 to *m* at each time period. The NPV of the baseline, the proposed project, and the project alternatives can then be compared. The option with the greatest NPV is the most economically desirable.

A common substitute to finding the NPV of each of the baseline, the proposed project, and the project alternatives is finding the benefit-cost ratio (B/C).[71] Adjusting for time value of money, the equation for benefit-cost ratio becomes:

$$B/C = \frac{\sum_{t=0}^{\infty}\sum_{j=1}^{n} B_{jt}(1+i)^{-t}}{\sum_{t=0}^{\infty}\sum_{k=1}^{m} C_{kt}(1+i)^{-t}}$$

The benefit-cost ratio provides a dimensionless summary measure of economic performance. The option with a B/C ratio greater than one is acceptable; however, the project alternative with the highest B/C ratio is economically desirable. This summary measure has several disadvantages. The order of magnitude of the benefits and costs are lost in the analysis, thereby limiting the scope of understanding which an informed decision can based. Because benefits and costs are relative to accounting perspectives, the benefit-cost ratio may be easily manipulated, and may vary significantly depending on how benefits and costs are classified. In some cases, the economical desirability of a project may be unclear:

- B/C = 0. The value of a project's benefits may be \$0, but its costs may be greater than \$0 or less than \$0. For example:

  B/C = 0 / -15 = 0 or B/C = 0 / 15 = 0

  In this case, the net financial impact of a project may positive or negative. The benefit-cost ratio does not provide adequate information for decision-making.
- B/C < 1. Depending on the accounting perspective, a project loss may be considered as a negative benefit and other impacts are positive or negative costs. In such a case, the value of a project's benefits are negative and the value of its costs may be negative and even less than the value of the benefits. For example:

  B/C = -15 / -30 = 0.5

  In this case, an economically advantageous project may have a ratio less than one. The B/C ratio alone fails to provide adequate information regarding a project's economic desirability.
- B/C = ∞. The value of a project's benefits may be positive or negative, but it may have no costs. For example:

  B/C = 10 / 0 = ∞ or B/C = -10 / 0 = ∞

  Again, the B/C ratio alone fails to provide adequate information regarding a project's economic desirability.

The above sample cases illustrate the failure of the B/C ratio in providing sufficient summary measure for decision making. The instability of benefit-cost ratio may lead to loss of credibility of the analysis.[72]

Other less common summary measures are available, but the above listed measures are typically used in Benefit-Cost Analysis performed by public agencies.

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[71] Sassone and Schaffer, p.19

[72] Lund, 1992.

These measures summarize the economic performance of the baseline, the proposed project, and the project alternatives, presenting the option that provides the greatest NPV or B/C ratio. They provide objective decision criteria that the decision-makers may assess when selecting a project.

Qualitative Measure. For benefits and costs that are not quantifiable, a scale indicating the magnitude of importance should be associated with each impact. A five-point scale, ranging from “high relative benefit” to “high relative cost” can be assigned to the impact, with smaller relative benefits and costs in the middle of the range.[73] To ensure support in the decision-making process, the assignment of these impacts to the scale should be performed with the involvement of relevant stakeholders and decision-makers.

Step 7: Select a Discount Rate.

The discount adjusts benefits and costs to account for time value of money and may be influenced by a combination of factors, including inflation, the public agency’s rate for financing capital projects, and the agency’s tolerance for risk and uncertainty. Federal guidelines presented in Circular No. A-94 from the Office of Management and Budget recommend a discount rate of seven percent (7%) for government-funded projects.[74] Local agencies typically have a policy in place which sets and standardizes discount rates for their investments in capital improvement projects.

Step 8: Calculate Summary Statistic Per Alternative and Compare.

Once a summary statistic and a discount rate are selected, the net present value can be calculated for the quantifiable benefits and costs associated with the recycled water project, the baseline, and the project alternatives. The net present value for each option can then be listed. Each of the project’s non-quantitative benefits and costs and their assigned scale of impact should be summarized so that their importance is not lost in decision-making.

Step 9: Perform Sensitivity Analysis.

Throughout each step of the Benefit-Cost Analysis, the analyst and sponsoring public agency must make assumptions, regarding costs, benefits, and discount rate for the recycled water project, the baseline, and alternative projects. These assumptions present uncertainty in the decision-making process. To better inform decision-makers, a sensitivity analysis should be performed to examine how small changes to these assumptions would affect the project’s summary performance. Two common methods of sensitivity analysis are the Variable-by-Variable Analysis and the Scenario Analysis.[75]

In the Variable-by-Variable Analysis, the effect of each variable on the quantitative summary measure is analyzed. Variables of greatest concern, such as capital cost or discount rate, are selected for each project alternative. These variables are

[73] Raucher, p. 31
[74] US Office of Management and Budget (OMB), Section 8.b.
[75] NCDER, Module 5, Section 3.

assumed to vary independently, one at a time. For each selected variable, an optimistic, most likely, and pessimistic values are selected and included in the calculation of the summary measure, normally the net present value.[76]

In Scenario Analysis, some variables are assumed to vary together, forming a scenario. Scenarios are selected for each option. For example, linked variables presented by a recycled project include capital cost for a recycled water treatment plant and the avoided costs of additional water supply and wastewater disposal capacity. For each scenario, the best case, most likely case, and worst case are selected and included in the calculation of the summary measure.[77]

For practical purposes, the scenario analysis must be limited to include only key variables or scenarios; otherwise, a daunting number of calculations may be performed and analyzed. Some input from relevant stakeholders may be required to establish the variables or scenarios to include in sensitivity analysis. Both methods of analysis indicate the stability, robustness, or range of the summary measure of each option. Given this information and the quantitative and qualitative summary measures for each of the baseline, the proposed project, and the project alternatives, decision-makers can be better informed regarding the option that most likely maximizes net benefits to their community, communities or region.

CASE STUDY: SAN RAMON VALLEY RECYCLED WATER PROGRAM

Background

Dublin San Ramon Services District (DSRSD, District) is located in a valley between the Altamont Hills and the Dublin Grade in the East Bay. The District provides potable water and recycled water distribution services to the City of Dublin, Parks Reserve Forces Training Area (PRFTA) (an adjacent military base), an unincorporated area of Alameda County, and Dougherty Valley (an unincorporated region of Contra Costa County). The District also provides wastewater collection and treatment for the City of Dublin, an unincorporated are of Alameda, and the southern portion of San Ramon, and wastewater treatment by contract for the City of Pleasanton. A location and service area map is shown on Figure 6.[78]

In the mid-1990's, extensive residential and commercial development began within the cities and counties in the District's service area as a response to a regional economic boom. This expansion demanded greater water capacity and wastewater treatment and discharge export capacity than the District could provide at that time. The District recognized that a water recycling program could provide some relief to both its water and wastewater challenges. Realizing that a water recycling program will require significant capital investments, and looking to achieve an economy of scale for its customers, the District sought to partner with its neighboring water district, East Bay Municipal Utilities District (EBMUD). EBMUD is a water service provider north of the District's service area. EBMUD faced the challenge of seeking and providing additional water capacity for the expansion of its service area in eastern Contra Costa County. Both

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[76] Ibid.
[77] Ibid.
[78] Dublin San Ramon Services District (DSRSD), http://dsrsd.com/aboutDSRSD/facts.html, 2008.

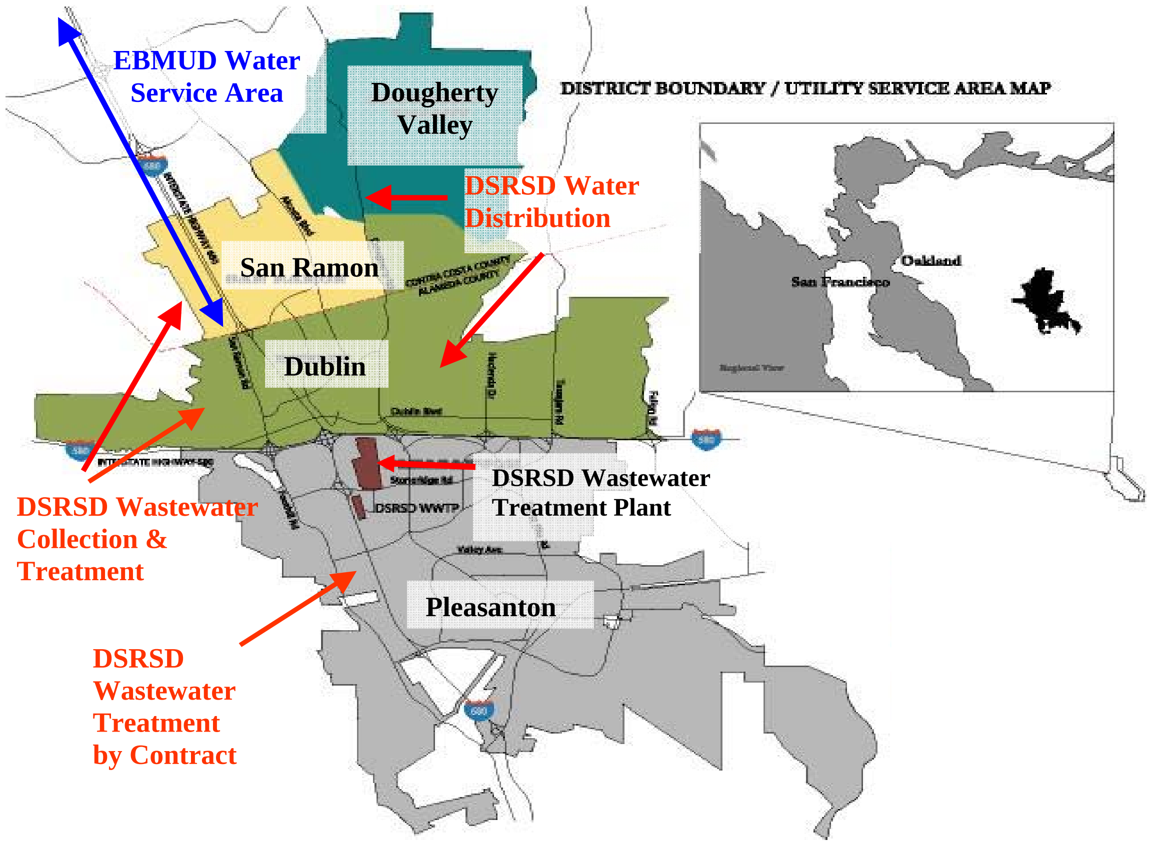

Figure 6. DSRSD Location and Service Area Map
(Courtesy of Dublin San Ramon Services District Engineering Department)

agencies have committed to pursuing a recycled water project. However, neither agencies have decided on a scale, schedule, nor financing commitments.

From the onset of their partnership discussions, both DSRSD and EBMUD were interested in maximizing benefits and minimizing costs to their customers associated with a recycled water project. Ultimately, DSRSD and EBMUD formed a joint powers authority called Dublin San Ramon Services District/East Bay Municipal Utilities District Recycled Water Authority (DERWA) to implement the San Ramon Valley Recycled Water Program, a multi-phased recycled water project that brought recycled water to customers in DSRSD and EBMUD.[79] In this section, a comparative analysis is performed on the agencies' joint partnership study and the framework for economic analysis presented in this paper.

Joint Water Recycling Program Study and the Framework for Economic Analysis

The Recycled Water Task Force has found that utility agencies commonly perform only financial analyses unless economic analyses are required by funding agencies such as the State Water Resources Control Board, Department of Water Resources, and the US Bureau of Reclamation for supplemental funding.[80] DSRSD and

[79] DERWA, www.derwa.org, 2008.
[80] Recycled Water Task Force, 2003, p. 47-48.

EBMUD are no exception to other utility agencies in California. Prior to forming a joint powers agency, both districts entered into a planning agreement and formed a steering committee in 1994 to conduct a study to analyze the feasibility of a joint recycled water project.[81] The joint water recycling program study is the closest that both agencies have come to performing a documented economic analysis for their recycled water program. The time horizon used was 25 years (to 2020), when both agencies anticipate ultimate buildout of their service area. To some degree, the study corresponds with the presented framework for economic analysis. Disparities between the study and the framework for economic analysis also were found. If those disparities were addressed, joint partnership negotiations may have been less costly and labor intensive for both agencies. The fit of the study with the framework for economic analysis is presented below.

Step 1: Develop an Accounting Perspective. The steering committee arrived at a natural accounting perspective. The area that can most feasibly be served with recycled water from DSRSD's wastewater treatment plant is the San Ramon Valley, a regional area that is mostly in DSRSD's water and wastewater service area and in the southeastern portion of EBMUD's water service area. Because DSRSD and EBMUD are the two funding agencies representing water and wastewater customers within the San Ramon Valley, both agencies' accounting perspectives are represented in the study. The steering committee comprised of two key staff members from each agency. DSRSD's objectives are to address its wastewater effluent disposal issues and obtain additional water supply for planned developments in its service area. EBMUD's objective is to augment its limited potable water supply to existing uses and planned developments in its service area. Both agencies' goals were to find an arrangement that would allow flexibility to adapt to changes, provide equity and protection for each district, provide a joint-partnership approach, provide ease of implementation, allow public acceptance, provide economic incentive to succeed, and minimize overall capital and operating costs.[82]

Step 2: Establish a Baseline Alternative. The steering committee established a status quo baseline for each agency in its analysis. Each agency's baseline would be to separately develop and implement its own water recycling project at its own cost, scale, and schedule.[83] In this particular case study, consideration of each agency's schedule is included as each agency has its own sense of urgency for a recycled water project and each agency's fall-back position is to pursue its own project. The agencies' baselines were used to compare with other alternatives in the next step.

Step 3: Identify Project Alternatives. The steering committee identified two broad agency arrangement alternatives and three project scenarios in the study. These alternatives and scenarios were studied because they were technically, politically, and legally possible for practical purposes. The two broad agency arrangements were:

- Alternative 1—Create a joint powers agency to develop and implement projects necessary for recycled water delivery; and,

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[81] Michalczyk, et al., 1995, p. 1.
[82] Ibid, Section 1.
[83] Ibid, Section 1 and 4.

- Alternative 2—Establish a lead district to develop and implement projects and provide service to the secondary district.

The three project scenarios varied the scale of the project:

- Scenario 1—Provide recycled water to all water user areas including existing customers, known approved development, and far future development projects in EBMUD's San Ramon Valley service area and the entire DSRSD service area;
- Scenario 2—Provide recycled water to existing demands in EBMUD's San Ramon Valley service area and known approved development in DSRSD's eastern Dublin service area; and,
- Scenario 3—Provide existing and far future development demands in EBMUD's San Ramon Valley service area and known approved development in DSRSD's eastern Dublin service area (Scenario 2 plus EBMUD's far future development demands). [84]

Through a public outreach program undertaken as part of the study, both agencies developed these scenarios with the input of relevant stakeholders. Relevant stakeholders included opinion leaders, community groups, and probable users in the communities the agencies serve. The agencies found that pricing and use policies were major issues with stakeholders. Construction impacts, development growth, and aesthetic impacts to plants and grasses were also issues of concern with stakeholders.[85]

Step 4: Identify Benefits and Costs for Proposed Project and Alternatives. To a limited degree, the steering committee identified the benefit and cost impacts for each agency arrangement alternative and project scenario. Each agency arrangement alternative's advantages and disadvantages were identified. The steering committee limited identification of benefits and costs of the scenarios to the financial and environmental categories. Capital costs and projected revenues for each scenario were identified. An initial environmental study was included in the report to discuss expected impacts of recycled water to the surrounding area.[86] However, no recreational, public health, and socio-economic equity considerations were identified. The steering committee did not include valuation for the cost of producing and conveying recycled water versus the cost of other new water supply options, reduced or delayed infrastructure costs, improved reliability of supply, and environmental benefits. Because these considerations and valuations are missing, the agencies may be missing key information to support their decisions.

Steps 5: Analyze Project Benefits and Costs. Because the benefits and costs presented by the three broad agency arrangement alternatives were difficult to quantify, the benefits and costs were analyzed qualitatively. The arrangement alternatives were qualitatively analyzed to the degree which each alternative meets the goals established by the agencies in Step 1.[87]

The steering committee performed financial analysis on each scenario for a twenty-year period. The direct benefits and costs of each scenario were quantified in

[84] Ibid, Sections 1 and 2.
[85] Ibid, Section 5.
[86] Ibid, Section 2 and Section 3.
[87] Ibid, Section 4.

monetary terms. Revenue projections were based on each agency's water rate and connection fee pricing and costs were based on construction cost estimates for capital improvements and each agency's operation and maintenance costs. The scenarios were also qualitatively analyzed as they relate to practicality of implementation and schedule.

Although, indirect benefits and costs associated with the environmental impacts were identified in the earlier step, no values were identified. These impacts are relevant to stakeholders, but were not included in the analysis.

Step 6: Select a Summary Measure. As discussed earlier, the benefits and costs of agency arrangement alternatives are difficult to quantify. The summary measure of "high relative benefit" to "high relative cost" was used but not explicitly itemized in the study. The agencies were asked to compare the individual alternative's advantages and disadvantages against the agencies' goals. For example, if a lead agency was established to provide recycled water to the other agency (Alternative 2), the lead agency would have the power to set its own system of recycled water rates and charges that may be greater than the potable water rates and charges of the other agency.[88] Recycled water may be difficult to market for the other agency. This factor alone provides "high relative cost" to the agencies.

The benefits and costs of the scenarios were quantifiable. Each scenario will deliver a different quantity of recycled water to each agency. To ensure fair comparison of the scenarios, the steering committee selected the net present value per unit volume for each scenario. The scenarios were also qualitatively measured based on their practicality and schedule.

Step 7: Select a Discount Rate. To account for time value of money and inflation, the two agencies agreed on a discount rate of seven percent (7%).[89] This discount rate is normal for most public agencies and conforms to federal guidelines.

Step 8: Calculate Summary Statistic Per Alternative and Compare. In Table 3, the steering committee's findings for the alternatives and scenarios are summarized and shown for comparison. The summary statistic for the three arrangement alternatives found that creating a joint powers agency to develop and implement recycled water projects (Alternative 1) provided more "high relative benefits" compared to the baseline alternative and Alternative 2. The steering committee recommended Alternative 1.

The quantifiable summary statistic for each scenario is follows: Scenario 1 is $794/acre-ft, Scenario 2 is $1,093/acre-ft, and Scenario 3 is $1,162/acre-ft. Qualitative factors were also recognized. For example, Scenario 1's future demands, which extend beyond the time set time horizon of planning, are highly uncertain and environmental impacts may be more significant. Scenario 2 has relatively lower capital and unit cost compared with Scenario 3.[90] Given these considerations, the steering committee recommended Scenario 2.

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[88] Ibid.
[89] Ibid, Section 2.
[90] Ibid.

Table 3. DSRSD/EBMUD Recycle Water Steering Committee Findings

Alternative/Scenario	Description	Findings
Alternative		
Alternative 0 (Baseline)	Each agency to develop and implement its own water recycling project at its own cost, scale, and schedule.	High Relative Costs
Alternative 1	Create a joint powers agency to develop and implement projects necessary for recycled water delivery	High Relative Benefits
Alternative 2	Establish a lead district to develop and implement projects and provide service to the secondary district	High Relative Costs
Scenarios		
Scenario 1	Provide recycled water to all water user areas including existing customers, known approved development, and far future development projects in EBMUD's San Ramon Valley service area and the entire DSRSD service area.	$794/acre-ft
Scenario 2	Provide recycled water to existing demands in EBMUD's San Ramon Valley service area and known approved development in DSRSD's eastern Dublin service area.	$1,093/acre-ft
Scenario 3	Provide existing and far future development demands in EBMUD's San Ramon Valley service area and known approved development in DSRSD's eastern Dublin service area (Scenario 2 plus EBMUD's far future development demands).	$1,162/acre-ft

Step 9: Perform Sensitivity Analysis. Throughout each step of their study, the steering committee made assumptions regarding costs, benefits, and discount rate for the recycled water project scenarios. These assumptions present uncertainty in the decision-making process. The steering committee performed two sensitivity analyses using the Scenario Analysis method, whereby some variables were assumed to vary together.

In the first sensitivity analysis, distribution pipelines in Scenarios 2 and 3 were extended and more customers were connected to the recycled water system. Despite increased cost of extending the distribution pipelines, the steering committee found an overall benefit of reduced per unit cost of delivery.[91] The extension of the pipeline increased proximity to more potential customers. It also addressed the aforementioned uncertain demands. This option would allow future expansion of service to developments that appear to be uncertain at the time of the analysis. Expansion can take place when those developments move forward. By performing this sensitivity analysis, decision makers are assured that extending the distribution pipelines would be cost effective.

In the second sensitivity analysis, the size of the main transmission pipeline in Scenario 2 was increased and the total project cost was determined. The steering committee found little impact to the total project cost.[92] By performing this sensitivity analysis, the decision makers are shown that the installation of a larger size main transmission pipeline allow both agencies the flexibility to provide recycled water to more customers in their service area in the future with minimum cost impacts. This option also would allow future expansion of service to developments that appear to be uncertain at the time of the analysis.

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[91] Ibid.
[92] Ibid.

Outcome of the San Ramon Valley Recycled Water Project

Shortly after the completion of the joint water recycling program study in 1995, DSRSD and EBMUD formed the DSRSD/EBMUD Recycled Water Authority (DERWA), a joint powers agency where both agencies interest are equally represented. DERWA is charged with the responsibility of developing and implementing projects necessary for recycled water delivery to both agencies' service areas. The DERWA board of directors consists of four members, two publicly-elected board members from each agency. In 1996, DERWA approved the San Ramon Valley Recycled Water Program (SRVRWP). The program will provide recycled water to expanded areas beyond that described in Scenario 2 at a cost of $85,960,000.[93] The program was approved to initially plan for a recycled water project that would optimize several objectives:

- to plan for treatment and distribution of recycled water up to the volume produced by DSRSD's wastewater treatment plant,
- to plan for a distribution system that would allow connection of customers with greatest recycled water demands,
- to distribute costs between the two agencies such that a recycled water enterprise jointly is less costly than each agency funding its own individual recycled water project,
- and to distribute costs between the two agencies such that the shared costs are equitable for both agencies and their customers. The two districts agreed on final distribution of recycled water deliveries and allocation of costs in 2003.[94]

Since less land development is occurring within EBMUD's San Ramon Valley service area, their portion of recycled water deliveries would be for existing users who are already connected to a water supply. Significant land development had commenced within DSRSD's service area and the need for wastewater effluent disposal and water supply was more urgent. During the eight years of cost negotiations, DSRSD took financial risk by installing major distribution infrastructure within its service area to take advantage of opportunities for cost savings presented by the construction of new developments within its service area. Because of the high level view of planning that was performed in the preliminary benefit-cost analysis, these kinds of costs were not included in that analysis. By the end of 2003, DSRSD completed construction of 75% of the backbone pipeline it was required to construct in its service area.[95] During the eight years of negotiations, both agencies incurred significant cost for consultants to conduct studies for each negotiating point. Attorneys costs for drafting and re-drafting agreements and contracts between the agencies was considerable. Cost for staff time devoted to negotiations and associated activities is also significant.

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[93] DERWA, http://www.derwa.org/faq.html, 2008.
[94] DSRSD, July 15, 2003.
[95] The author was the DSRSD's project manager for these recycled water pipeline installation projects.

Discussion on the Joint Program Study and the Framework for Economic Analysis

In this section, the DSRSD/EBMUD joint study for the San Ramon Valley Recycled Water Program was compared to the framework for economic analysis presented in this paper. This joint study was not meant to provide a rigorous economic analysis for the program; however, the study is the closest that both agencies have come to performing a documented economic analysis for their recycled water program. To some degree, the study corresponds with the steps outlined in the framework for economic analysis, illustrating the practical application of the framework.

Given that the joint study is not a rigorous economic analysis for the program, disparities between the study and the framework for economic analysis also were found. The two agencies' objectives and their schedules for recycled water program implementation were not fully developed. Benefits and costs considerations for the scenarios were limited to financial analysis. Stakeholder input was limited. Qualitative benefits and costs analysis was limited to the perspective of the agencies. Baseline alternative considerations did not include the option of each agency pursuing a recycled water project individually.

A rigorous economic analysis within the framework provided in this paper would have provided a holistic analysis that may have considerably shortened the eight-year cost allocation negotiation that both districts undertook. The analysis would have documented the objectives of the agencies, including schedule, and the major benefits and costs of the program as they relate to the stakeholders within the agencies' service area. The analysis would have included the value of each agency individually pursuing a recycled water project. The documentation of the objectives, benefits and costs, and other alternatives in the analysis would have provided consistent supplemental information to the agencies' decision makers, publicly-elected board members who enter and leave office. An economic analysis would have provided additional guidelines to decision-makers as they decide if a recycled water program should be pursued and how the benefits and costs of recycled water are distributed within their communities.

RISK IN DECISION-MAKING

In each step of a project, from selection to construction to operations, decisions are made with some uncertainty in the predicted outcome. Uncertainty can be introduced by variables such as financial costs, discount rate fluctuation, and implementation made after the analysis by relevant stakeholders or decision makers. Variation in the final outcome of a project presents risk in the decision-making process. Risk can be analyzed in advanced by assigning probabilities to potential outcomes.[96]

RISK ANALYSIS USING EXPECTED-VALUE ANALYSIS

Expected-Value Analysis is typically used to deal with risks involved in project decision-making. This approach is particularly appropriate where the worst plausible consequences are not catastrophic. Probability estimates are assigned to alternative outcomes to determine expected outcome. The expected value of a project is calculated by the sum of the value of each outcome multiplied by the probability of each outcome, less initial cost in proceeding with the project. The equation for expected value is:

$$EV = \sum_{i=1}^{n} (P)(V) - C$$

where, *EV* is the expected value, *C* is the initial cost of a project, and *i* represents outcomes 1 to *n* with a probability of *P* and a value of *V*.

Probability estimates may be developed in several ways. For some variables, planning documents and literature are available. For example, projections for variables such as the population growth and increase water demands are available from which probabilities can be derived. The experiences of other utilities who have implemented recycled water projects also can be used as to develop probability estimates. For example, many California utilities have found that as end-users adopt recycled water as part of their water supply, they propose uses for recycled water not anticipated at the onset of the recycled water program. These new uses may increase demand and/or require additional treatment. Analysts and decision-makers should include risk analysis on impacts of increased demands and increased treatment requirements.

Other cases exist where decision-makers are faced with variables without future projections. In these cases, the decision-makers must develop subjective probability estimates, accounting for combinations of variables. This method is illustrated in the following case study. Decision-makers should use risk analysis as another tool in the decision-making process so that they can best maximize the value of their constituent’s investments.

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[96] Ibid, Module 5, Section 1.

CASE STUDY: RISK ANALYSIS FOR CLEAN WATER REVIVAL

Background

Dublin San Ramon Services District (DSRSD) is described in the earlier case study in this paper. As described earlier, the District was experiencing a regional economic boom in 1995. This expansion demanded greater water capacity and wastewater treatment and discharge export capacity than the District could provide at that time. The San Ramon Valley Recycled Water Project described in the earlier case study partially addresses both issues. However, the San Ramon Valley Recycled Water Project would not provide sufficient recycled water during peak demands during the dry weather and sufficient wastewater disposal during the wet season. The District began planning for a project called Clean Water Revival (CWR) to solve both problems. The project was to treat 3 million gallons per day (MGD) of secondary treated wastewater effluent with microfiltration and reverse osmosis. The treated water would be mixed with groundwater then exported to wells for injection into the groundwater basin for replenishment and salt control. Injection would occur during the wet season, when recycled water demands are low. Groundwater replenishment would allow for increased extraction during the dry season. The $8M project would be the first attempt in the industry to inject demineralized water into a confined groundwater basin.[97] Ultimately, the treatment facilities and pipeline were constructed; however, these facilities were never used for groundwater injection. In this section, a retrospective analysis is conducted on the risks that the District undertook that led to the progression of the project to construction completion given the possibility that the facilities may not be put into service as intended.

The Decision-Makers

DSRSD is a water retailer and a wastewater service provider in a geographically constrained area inland from the San Francisco Bay. Implementing its plans for water and wastewater capacity expansions required coordination and agreement with various public entities within the valley. Each of these entities had a voice in the progress of CWR. The entities, their roles, and interests are listed below.

The Cities of Dublin and San Ramon, and portions of unincorporated regions of Contra Costa County and Alameda County are communities served by DSRSD. They comprise less than 25% of the population in the area, but they are the driving force behind the need for wastewater export capacity because of these communities' planned expansion. These communities also are the funding source for the CWR.

The neighboring Cities of Pleasanton and Livermore, which jointly have approximately 75% of the population in the area, share the groundwater basin and a wastewater export pipeline with the District. Together with DSRSD, they formed Livermore-Amador Valley Water Management Authority (LAVWMA), a joint powers authority to manage a pipeline that exports wastewater effluent from the valley for eventual discharge to San Francisco Bay. The pipeline is old and requires major rehabilitation. The expansion of the pipeline during rehabilitation would provide the District opportunity for significant cost savings if construction cost is shared among

[97] DSRSD, Resolution 45-02, October 17, 2002

participants. Because of the cities' membership in LAVWMA and their interest in the groundwater basin, their voices carry significant weight in the continuance of CWR.

Zone 7 Water Agency (Zone 7) is the water wholesaler for the valley. Zone 7 has water rights and contracts to the Delta and State Water Project, and the groundwater basin in the valley. This agency treats and distributes water to the cities of Pleasanton and Livermore, DSRSD, and the California Water Service Company, a water retailer in a southern portion of Livermore. During most of the year, Zone 7 imports the water into the valley. During the drier months, it extracts water from the groundwater basin. Zone 7's concerns include protecting the viability of the groundwater basin as a potable water source and mitigating the groundwater basin's increasing salt concentration. Because Zone 7's customers include DSRSD, Livermore, and Pleasanton, its groundwater management decisions are largely influenced by these cities. Its role as groundwater basin manager gives its voice great weight in the continuance of CWR.

Risk Analysis for the Project

In 1993, the City of Dublin approved the East Dublin Specific Plan which would almost triple DSRSD's wastewater disposal capacity required in the LAVWMA pipeline. The communities anticipated a long negotiation and expansion process. Furthermore, it was uncertain if the pipeline expansion would provide adequate capacity. Therefore, in 1994, the District, Livermore, and Zone 7 applied for and received a master recycling permit from the San Francisco Bay Area Regional Water Quality Control Board (RWQCB). The permit would allow Livermore and DSRSD to construct recycling facilities and inject purified water into the valley's groundwater basin, from which Zone 7 obtains water to treat and resell as potable water in the valley.[98]

By the end of 1994, negotiations regarding the LAVWMA pipeline expansion were deadlocked. Negotiation had impassed over issues such as allowing pipeline expansion, segments to rehabilitate, schedule, and cost sharing influenced, motivating the CWR project as an alternative to LAVWMA export pipeline expansion. The total cost of pipeline rehabilitation and expansion were expected to be approximately $200M.[99] The District commenced planning for Clean Water Revival, with an initial 3 MGD capacity and intention to be expandable to meet future wastewater production. The initial project was expected to cost $8M.[100]

This recycled water project started with support from the surrounding cities and Zone 7. At the time, the 1987-1992 drought[101] had just ended and memories of water rationing and shortages were fresh in the minds of the Tri-Valley residents. Furthermore, the drought had required Zone 7 to draw more than normal volumes from the groundwater basin, increasing salt concentration there. The Cities saw CWR as insurance against future droughts; Zone 7 saw the project as a way to mitigate high salt concentration in the groundwater basin. When the draft Environmental Impact Report (EIR) was published for public review in October 1996, most of the interested parties

[98] Ibid.
[99] DSRSD, Comprehensive Annual Report for 2001
[100] DSRSD, Resolution 45-02, October 17, 2002
[101] State of California, Department of Water Resources, Preparing for California's Next Drought, July 2000.

provided comments recommending approval for the project so that water could be recycled. In 1997, the EIR was certified and project construction commenced.[102]

DSRSD must have believed at the time that support for the project was tenuous. The support was present for a 3 MGD CWR project; however, further expansion may not be met with as much support, especially because an anti-growth citizens group was gaining voice. DSRSD continued to negotiate with Pleasanton and Livermore for the LAVWMA pipeline expansion. Late in 1997, a tentative agreement was reached regarding the LAVWMA pipeline capacity.[103] At that point, the probability of CWR's continuation was reduced to less than 100%.

The decision tree for the continuation of CWR is illustrated in Figure 7. A decision tree add-in for the Microsoft Excel program was used to create the tree. Subjective probability values were assigned to each event scenario based on past relationships, political climate at that time, and outcomes of past agreements among the entities. The decision to proceed with the project is based on minimizing projected cost and minimizing delay to attaining wastewater export capacity.

If DSRSD were to proceed with CWR at an expected cost of $8M, its continuance hinges on support from Pleasanton and Livermore. The increasing voice of anti-growth citizens groups, which support the agenda of a minority of each city's council members, implies a high probability that Pleasanton and Livermore will withdraw their support. Still, both communities recognize the value of recycled water and there was still a good probability that the cities would support the project.

Because Pleasanton and Livermore are amongst Zone 7's largest customers, Zone 7's support for CWR would be largely influenced by them; however, Zone 7 also is influenced by concerns regarding salt concentrations in the groundwater basin. The probability that Zone 7 would support the project is low if neither city supports the project, greater if one does, and highest if both cities support the project. With lack of support from any or all parties, DSRSD would expect to incur legal costs to exert its right to recycled and inject water in the groundwater basin, with little certainty of judicial success. This exercise would also incur delays to obtaining wastewater export capacity.

If CWR does not progress, DSRSD may take one of three courses. It may continue to pursue LAVWMA pipeline expansion negotiations at significant delay and expected expansion cost from a more difficult negotiating position. It may proceed to construct a pipeline parallel to LAVWMA at a cost significantly higher than the expansion cost. Or, DSRSD may take no action thereby incurring the most significant cost to the community. For illustrative purposes, the expected cost for the parallel pipe is estimated at 2.5 factor of the expansion cost, and the no-action cost is estimated in the magnitude of billions of dollars, though they may actually be more. Legal cost incurred in these latter scenarios may be greater than if CWR progresses, but they are not included in the analysis since the cost is several orders of magnitude less than the cost of the these scenarios.

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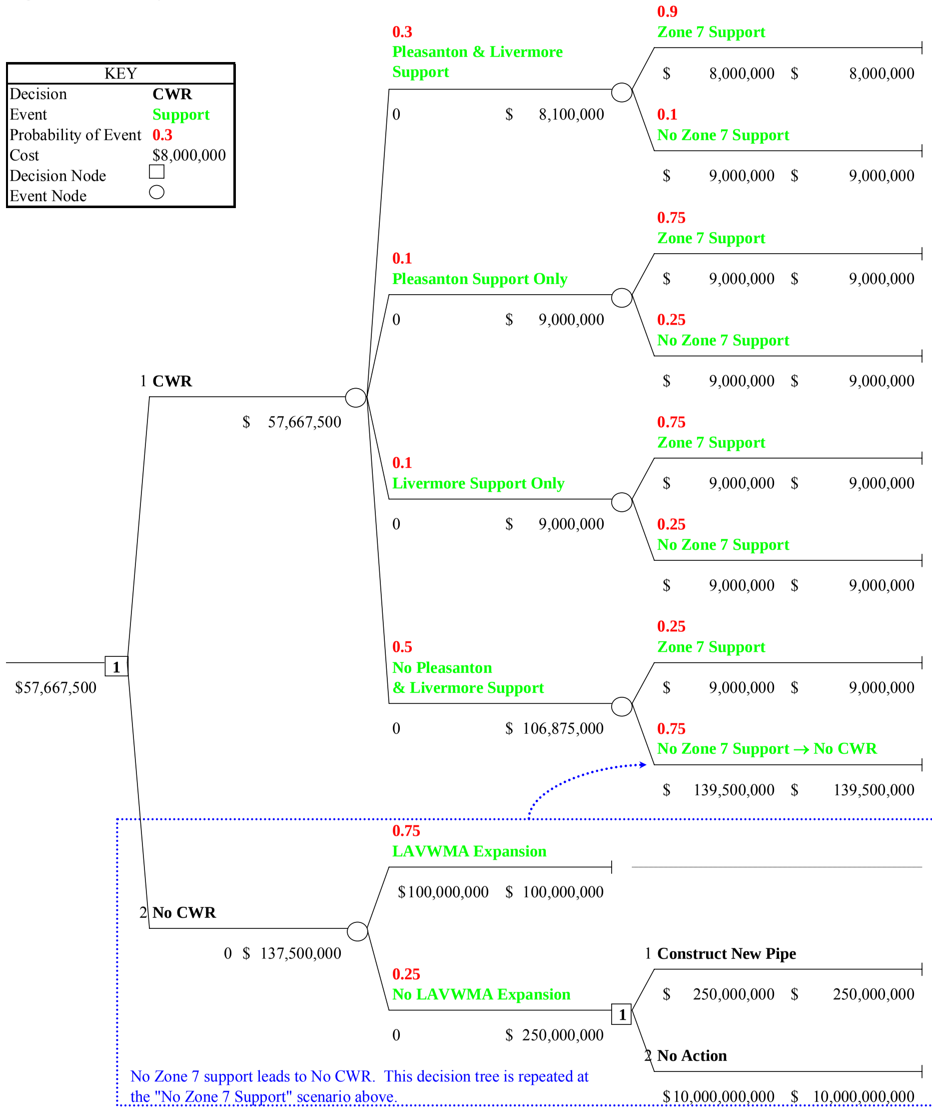
[102] DSRSD, Resolution 45-02, October 17, 2002.
[103] Ibid.

Figure 7. Risk Analysis Decision Tree for Clean Water Revival



Cost Outcome	Notes
$ 8,000,000	Future capital cost for expansion not included. No Delay
$ 9,000,000	Future capital cost for expansion not included. Legal Cost estimated at $1M for the purposes of this analysis only. Project delay expected.
$ 9,000,000	Future capital cost for expansion not included. Legal Cost estimated at $1M for the purposes of this analysis only. Project delay expected.
$ 9,000,000	Future capital cost for expansion not included. Legal Cost estimated at $1M for the purposes of this analysis only. Project delay expected.
$ 9,000,000	Future capital cost for expansion not included. Legal Cost estimated at $1M for the purposes of this analysis only. Project delay expected.
$ 9,000,000	Future capital cost for expansion not included. Legal Cost estimated at $1M for the purposes of this analysis only. Project delay expected.
$ 9,000,000	Future capital cost for expansion not included. Legal Cost estimated at $1M for the purposes of this analysis only. Project delay expected.
$ 139,500,000	*This leads to the "No CWR" decision tree below, and its expected cost.* Future capital cost for expansion not included. Additional legal cost estimated at $2M added for this analysis only. Significant project delay expected.
$ 100,000,000	Significant project delay expected. (Does not include DSRSD's share in pipe rehabilitation cost.) Significant legal cost not included due to difference in scale of magnitude
$ 250,000,000	Significant project delay expected. (Estimated cost, marked up from rehabilitation & expansion cost estimate Significant legal cost not included due to difference in scale of magnitude
$ 10,000,000,000	Most significant legal costs and delay expected. (Rough estimate of cost to DSRSD and community.) *For illustrative purposes only for this analysis.* Significant legal cost not included due to difference in scale of magnitude

Table 4. CWR Scenario Probabilities and Cost

Decision	Event		Expected Cost
	City Support (Probability)	Zone 7 Support (Probability)	
CWR	Pleasanton & Livermore (0.3)	Yes (0.9)	$8,000,000
	Pleasanton & Livermore (0.3)	No (0.1)	$9,000,000
	Pleasanton (0.1)	Yes (0.75)	$9,000,000
	Pleasanton (0.1)	No (0.25)	$9,000,000
	Livermore (0.1)	Yes (0.75)	$9,000,000
	Livermore (0.1)	No (0.25)	$9,000,000
	None (0.5)	Yes (0.25)	$9,000,000
	None (0.5)	Yes (0.75)	$139,500,000*
No CWR	LAVWMA Expansion		$100,000,000
	No LAVWMA expansion, construct new pipe		$250,000,000
	No LAVWMA expansion, no action		$100,000,000,000

**Expected Cost of No CWR + Estimated Legal Costs*

The assigned probability values are indicated above each event, and the expected costs are indicated below each event in the decision tree. The events, probabilities, and costs are summarized in Table 4. The decision tree add-in in Microsoft Excel calculates the cost at event nodes given the probability and cost of an event. For example, the expected value of CWR if both Pleasanton and Livermore support the project is:

EV(Pleasanton & Livermore Support)

= Pr(Zone 7 Support) x EC(Zone 7 Support)
+ Pr(No Zone 7 Support) x EC(No Zone 7 Support)

= 0.9 x $8,000,000 + 0.1 x $9,000,000

= $8,100,000

Using this add-in, DSRSD's optimum, least cost decision in 1997 can be calculated.

The expected costs are estimated present value (1995) costs with delay costs taken into account. At best, all influential entities would support the project at a cost of $8M and minimum delay. Add the chance that Zone 7 may withdraw its support, delay would be incurred and expected cost would increase to $8.1M. If only one city supports the project, the expected cost would be $9,000,000. If both cities do not support the project, the expected cost increases to $139,500,000. Note that delay costs would be significant. This expected cost is heavily influence by the increased possibility that Zone 7 may withdraw its support and the expected cost of No CWR project. Overall, pursuing CWR would have an expected cost of $57,667,500. If the project proceeds, it may be expanded in the future, as the DSRSD service area grows, at the future cost of the technology.

If the District were not to pursue CWR, it may pursue negotiations for the LAVWMA expansion at a cost of approximately $100M. The District must somehow move the deadlocked negotiations along; the expected delay would be greater than if it were to pursue CWR. The other option in obtaining additional wastewater export capacity is to construct another force main, parallel to LAVWMA, at an estimated cost of $250M—this cost is estimated from the expected rehabilitation and expansion cost of LAVWMA, multiplied by 2.5 for the purposes of this illustrative analysis. The delay for this option may be equal to that of the earlier option, as the District must obtain funds for the project. Lastly, if the District takes no action, the community and the District will incur significant cost. The District would expect the most significant legal cost here, as the developers of the newly approved communities would file suits against the District, along with the Cities of Dublin and San Ramon. For the purposes of this exercise, the cost of not taking action is roughly estimated to be $10 billion over the time horizon of planning. Overall, not pursuing CWR would have an expected cost of $137.5M.

Given the choice of pursuing CWR at an expected cost of pursuing CWR at an expected cost of $57,667,500, or not pursuing CWR at an expected cost of $137,500,000, this analysis indicates that DSRSD should choose to proceed with CWR. This choice is the least costly alternative, in terms of funds and delay to achieving wastewater export capacity. DSRSD did choose to proceed with CWR, the outcome is discussed below.

Outcome of Clean Water Revival

During the final phase of construction, the Cities of Pleasanton and Livermore and Zone 7 withdrew their support of CWR. In October 1998, the CWR treatment and pipeline facilities were completed, with the exception of the groundwater wells. The District proceeded with a comprehensive testing program to demonstrate that the facilities can produce water that would meet or exceed regulatory requirements for groundwater replenishment. Furthermore, the District conducted public opinion surveys to assess the public's acceptance of CWR groundwater injection, with inconclusive results. In 2000, Pleasanton and Zone 7 filed lawsuits to oppose groundwater replenishment.[104]

From 1997 to the early 2000's, the fear that recycled water would actually be injected in the groundwater basin increased for Cities of Pleasanton and Livermore and Zone 7. They now saw CWR's success in meeting or exceeding all regulatory water quality requirements as a threat to the valley's drinking water. The negotiation for LAVWMA expansion moved forward, and the Cities of Pleasanton and Livermore conceded to allowing the expansion and leasing their share of wastewater export capacity to DSRSD during the construction phase. In return, the District would have to agree not inject recycled water into the valley's groundwater basin. Given this concession, and the 2002 judgment ruling that would require the District to re-apply for a permit through the RWQCB, the District passed a resolution that modified the use of the CWR treatment facilities to provide water for landscape irrigation and eliminated the injection function.[105]

Discussion of Risk Analysis for Clean Water Revival

In this section, a retrospective risk analysis of the decision process was performed for a project that progressed through construction completion given the possibility that the facilities may not be put into service as intended. Subjective probabilities were assigned to different scenarios, and expected costs were calculated. The analysis was performed for a period just prior to project construction. This analysis recommended the same decision that the District made at that time. The actual final outcome of the project may have been predicted if the risk analysis and the decision tree were extended further and more scenarios were explored. This exercise illustrates the effectiveness of risk

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[104] Ibid.
[105] Ibid.

analysis and methodology of assignment of subjective probabilities in the process of risk analysis and decision-making.

DISCUSSION

In 1991, the California legislature adopted the *Water Recycling Act of 1991*, which established a statewide goal to recycle 700,000 acre-feet per year by 2000 and 1,000,000 acre-feet per year by 2010.[106] In the latest survey by the California State Water Resources Control Board, Office of Water Recycling, statewide water reuse is 525,460 acre-feet per year in 2003. Due to a variety of issues, communities statewide failed to meet the year 2000 goal and may fail to meet the 2010 goal. Financial and economic issues are at the forefront of these decisions. California's Recycled Water Task Force has identified funding issues and economics in water recycling as two of the six high priority issues for communities considering water recycling in the State.[107] The investment requirements appear high compared to the benefits for communities that have yet to invest in water reuse projects. Capital costs are incurred with the construction of a recycled water treatment plant and the installation of a new distribution system of pump stations, storage tanks and pipelines, which most likely will need to be installed under existing streets. Costs are localized, whereas benefits are far reaching and difficult to quantify. Benefits are often qualitative and difficult to quantify. Additionally, in areas where recycled water use is limited, the public perception of recycled water is often negative. Pursuing a water reuse program requires extensive investment in cost and time by public agencies or utilities and the communities that they serve. It requires effort and risks in involving stakeholders. Other alternatives to obtain water supply and discharge capacities appear less expensive. Water reuse projects can appear daunting.

Unfortunately, utility agencies commonly perform only financial analyses unless economic analyses are required by funding agencies, such as the State Water Resources Control Board, Department of Water Resources, and the US Bureau of Reclamation, for supplemental funding.[108] Further, each funding agency has a different economic analysis process and criteria. The Recycled Water Task Force recommended the development of a uniform analytical method for economic analyses and a uniform economic feasibility framework.[109]

California's limited water resources continue to be stressed. Urban populations in California communities continue to increase, along with their increased water supply demands and wastewater disposal. Agricultural and environmental demands provide additional pressure. On August 31, 2007, a federal district judge issued an order reducing the State's pumping from the Bay Delta by up to 35% to aid the endangered Delta Smelt, affecting communities in the San Francisco Bay Area and central and southern California that obtain water through the California State Water Project.[110] As these communities brace for water conservation and review other alternative water resources, pursuing or expanding recycled water projects should be reviewed as alternative using economic evaluation as a decision aid. The recent case with the Delta Smelt illustrates that communities far from the Delta can achieve benefits by using recycled water.

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[106] California Law, Chapter 7.5, Section 13577.
[107] Recycled Water Task Force, p. 19.
[108] Ibid, p. 47-48.
[109] Ibid, p. 49.
[110] Fimrite, September 1, 2007.

Addressing the financial and economic issues related to recycled water projects may increase water recycling in the state and reduce stresses in the state's water resources. Economic evaluation using the Benefit-Cost Analysis framework described in this paper will provide a holistic analysis for recycled water projects. Identifying and analyzing a recycled water project's benefits and costs quantitatively and qualitatively, with the involvement of relevant stakeholders, may reveal that the pursuing or expanding a recycled water project is a sensible investment. In identifying benefits, the beneficiaries are also identified and the financial cost can be distributed. As benefits are far-reaching, communities in a region should cooperatively pursue a recycled water project to share in the benefits and costs.

In performing an economic evaluation, risk and uncertainties also should be analyzed. Decision-makers should have some vision of the impacts of their decision and the direction that their decision may lead to. Experiences of utilities that have implemented water reuse projects may be used to assess the risk and uncertainties of having a water reuse enterprise. Challenges in the planning, design, construction, and start-up of a project may affect financial costs and/or delay or derail projects, as illustrated by the risk analysis case study. Changes in the direction of their market—their customers' demand and application—may increase capital cost, but also may increase revenues and other benefits. Changes in regulatory requirements also may require modifications in the treatment processes and restriction in application, thereby increasing financial cost and/or limiting revenues. Many utilities have successfully dealt with these challenges. The probability of these occurrences should be evaluated so that decision-makers can evaluate the comparative value of their alternatives.

Performing economic evaluation and risk analysis with transparency when assessing alternatives to a community' water resource issues can improve the likelihood of a successful project. The input of relevant stakeholders can provide a holistic view of benefits and costs. The values of the community can be revealed, along with their willingness to pay for water resource reliability and sustainability. The Benefit-Cost Analysis framework described in this paper allows for such transparency in decision-making. Given the opportunity to have their voices considered, relevant stakeholders may provide their support for a project. Such public support can help make a successful project.

CONCLUSION

For most communities in California, expansion is inevitable, along with future droughts. Creative water resource management strategies must be employed to provide for increasing water demands and wastewater discharge. Wastewater effluent collected, treated, and returned for reuse can be an additional water resource. Agricultural and landscape irrigation are the dominant uses for recycled water in California. Communities within the state are innovating to find other beneficial applications for recycled water, including groundwater recharge, seawater barrier, industrial use, recreational impoundment, and wildlife habitat establishment. They have found that recycled water provides a solution to multiple water concerns. Still, only 10 percent of the state's wastewater effluent is currently reclaimed for reuse. Communities statewide may fail California's 1991 goal to recycle 1,000,000 acre-feet per year by 2010. The State's Recycled Water Task Force found that funding and economic issues are two of the six main issues that hinder the increase of recycled water use in the state.

Establishing a recycled water program seems economically daunting for communities. Communities must expand their evaluation beyond the infrastructure needed to treat and distribute recycled water. Because water reuse involves multiple objectives, it can become more economically viable to implement. Unfortunately, the benefits of water reuse are far-reaching and indirect, whereas its costs are localized. Economic evaluation using the Benefit-Cost Analysis is a generally accepted process for projects that are funded by the government and serve the general public. It provides a more holistic assessment of the overall impact of a recycled water project to the public.

A framework for Benefit-Cost Analysis is presented in this paper that incorporates both the quantitative and qualitative impacts of recycled water projects. The initial step in performing the analysis is to establish an accounting perspective that will be used to assess the benefits and costs of a project. For recycled water programs, an accounting perspective that will achieve a reasonable economy of scale for the benefits to be captured and costs to be shared will lead to a successful project. A regional perspective, which involves wastewater utilities, water utilities, and multiple local communities, provides a sufficient scale.

Benefit-Cost Analysis requires comparison of water reuse projects to a baseline alternative and other project alternatives. The baseline, the water reuse project, and other project alternatives should be compared to one another to identify the best economic course of action for the public agency or utility and the community that it serves. The baseline alternative should identify the objectives to be met and provide a view of the future with no action towards improving long-range plans. Other proposed project and the project alternatives should address the objectives being sought and should be technically, politically, and legally feasible.

For each water reuse project, the baseline, and the alternative projects, benefits and costs should be identified and analyzed, quantitatively and qualitatively. Impacts are identified as benefits or costs depending on the accounting perspective selected earlier. To the extent feasible, benefits and costs should be quantified in monetary terms. Qualitative impacts should be highlighted and their value to the communities should be described. A summary measure and a discount rate can be applied to the quantifiable impacts; and a qualitative summary measure of level of benefit or cost can be assigned to unquantifiable impacts. Decision-makers may use the results of the summary measure in their decision-making.

For informed decision-making, uncertainties and risks also should be assessed. To address uncertainties presented by assumptions in the analysis, a sensitivity analysis should be performed by varying those assumptions. The extent of the impact of variables to each alternative project's summary measure should be identified. Risk of changes to the predicted final outcome of the project may be assessed by estimating the probability of various outcomes and calculating an expected value.

Formal economic evaluation befits the public sector's objectives in decision making. This analytical method satisfies the public policy direction to improve the welfare of society by maximizing net social benefits, and provides a means to improve social equity. Benefit-Cost Analysis and risk analysis are effective tools to a more holistically view of the impacts of projects and their alternatives. By including benefits and costs beyond cash flow, analysis results may be favorable to water reuse projects.

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APPENDIX A

Recycled Water Uses Allowed in California

Recycled Water Uses[1] Allowed in California[111]

*This summary is prepared by **WateReuse Association**, from the September 1998 draft of proposed Title-22 revisions and supersedes previous versions.*

Irrigation	Treatment Levels			
	Disinfected Tertiary Recycled Water	Disinfected Secondary-2.2 Recycled Water	Disinfected Secondary-23 Recycled Water	Undisinfected Secondary Recycled Water
Food crops where recycled water contacts the edible portion of the crop, including all root crops	**Allowed**	Not allowed	Not allowed	Not allowed
Parks and playgrounds	**Allowed**	Not allowed	Not allowed	Not allowed
School yards	**Allowed**	Not allowed	Not allowed	Not allowed
Residential landscaping	**Allowed**	Not allowed	Not allowed	Not allowed
Unrestricted access golf courses	**Allowed**	Not allowed	Not allowed	Not allowed
Any other irrigation uses not prohibited by other provisions of the California Code of Regulations	**Allowed**	Not allowed	Not allowed	Not allowed
Food crops where edible portion is produced above ground and not contacted by recycled water	**Allowed**	**Allowed**	Not allowed	Not allowed
Cemeteries	**Allowed**	**Allowed**	**Allowed**	Not allowed
Freeway landscaping	**Allowed**	**Allowed**	**Allowed**	Not allowed
Restricted access golf courses	**Allowed**	**Allowed**	**Allowed**	Not allowed
Ornamental nursery stock and sod farms	**Allowed**	**Allowed**	**Allowed**	Not allowed
Pasture for milk animals	**Allowed**	**Allowed**	**Allowed**	Not allowed
Nonedible vegetation with access control to prevent use as a park, playground or school yard	**Allowed**	**Allowed**	**Allowed**	Not allowed
Orchards with no contact between edible portion and recycled water	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Vineyards with no contact between edible portion and recycled water	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Non food-bearing trees, including Christmas trees not irrigated less than 14 days before harvest	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Fodder crops (e.g. alfalfa) and fiber crops (e.g. cotton)	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Seed crops not eaten by humans	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Food crops that undergo commercial pathogen-destroying processing before consumption by humans	**Allowed**	**Allowed**	**Allowed**	**Allowed**
Ornamental nursery stock, sod farms not irrigated less than 14 days before harvest	**Allowed**	**Allowed**	**Allowed**	**Allowed**

[111] WateReuse Association, 2007.

Supply for Impoundment	Treatment Levels			
	Disinfected Tertiary Recycled Water	Disinfected Secondary-2.2 Recycled Water	Disinfected Secondary-23 Recycled Water	Undisinfected Secondary Recycled Water
Non-restricted recreational impoundments, with supplemental monitoring for pathogenic organisms	**Allowed** [2]	Not allowed	Not allowed	Not allowed
Restricted recreational impoundments and publicly accessible fish hatcheries	**Allowed**	**Allowed**	Not allowed	Not allowed
Landscape impoundments without decorative fountains	**Allowed**	**Allowed**	**Allowed**	Not allowed

Supply for Cooling or Air Conditioning	Treatment Levels			
	Disinfected Tertiary Recycled Water	Disinfected Secondary-2.2 Recycled Water	Disinfected Secondary-23 Recycled Water	Undisinfected Secondary Recycled Water
Industrial or commercial cooling or air conditioning involving cooling tower, evaporative condenser, or spraying that creates a mist	**Allowed** [3]	Not allowed	Not allowed	Not allowed
Industrial or commercial cooling or air conditioning not involving a cooling tower, evaporative condenser, or spraying that creates a mist	**Allowed**	**Allowed**	**Allowed**	Not allowed

Other Uses	Treatment Levels			
	Disinfected Tertiary Recycled Water	Disinfected Secondary-2.2 Recycled Water	Disinfected Secondary-23 Recycled Water	Undisinfected Secondary Recycled Water
Groundwater recharge	**Allowed under special case-by-case permits by RWQCBs** [4]			
Flushing toilets and urinals	**Allowed**	Not allowed	Not allowed	Not allowed
Priming drain traps	**Allowed**	Not allowed	Not allowed	Not allowed
Industrial process water that may contact workers	**Allowed**	Not allowed	Not allowed	Not allowed
Structural fire fighting	**Allowed**	Not allowed	Not allowed	Not allowed
Decorative fountains	**Allowed**	Not allowed	Not allowed	Not allowed
Commercial laundries	**Allowed**	Not allowed	Not allowed	Not allowed
Consolidation of backfill material around potable water pipelines	**Allowed**	Not allowed	Not allowed	Not allowed
Artificial snow making for commercial outdoor uses	**Allowed**	Not allowed	Not allowed	Not allowed
Commercial car washes not done by hand & excluding the general public from washing process	**Allowed**	Not allowed	Not allowed	Not allowed
Industrial boiler feed	**Allowed**	**Allowed**	**Allowed**	Not allowed
Nonstructural fire fighting	**Allowed**	**Allowed**	**Allowed**	Not allowed
Backfill consolidation around nonpotable piping	**Allowed**	**Allowed**	**Allowed**	Not allowed
Soil compaction	**Allowed**	**Allowed**	**Allowed**	Not allowed
Mixing concrete	**Allowed**	**Allowed**	**Allowed**	Not allowed
Dust control on roads and streets	**Allowed**	**Allowed**	**Allowed**	Not allowed
Cleaning roads, sidewalks and outdoor work areas	**Allowed**	**Allowed**	**Allowed**	Not allowed
Flushing sanitary sewers	**Allowed**	**Allowed**	**Allowed**	**Allowed**

[1] Refer to the full text of the latest version of Title-22: California Water Recycling Criteria. This chart is only a guide to the September 1998 version.
[2] With "conventional tertiary treatment." Additional monitoring for two years or more is necessary with direct filtration.
[3] Drift Eliminators and/or biocides are required if public or employees can be exposed to mist.
[4] Refer to Groundwater Recharge Guidelines, California Department of Health Services.