

Integrated Water, Wastewater, and Energy Conservation: Enhanced Benefits Through Multi-Resource Planning

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Utility resource planning has traditionally evaluated water, energy, and wastewater resources in isolation from each other and from wider resource implications. Energy conservation planning methods have only recently begun to look beyond immediate energy and capacity savings toward broader benefits of environmental protection and energy security. Water conservation planning methods have generally lagged several years behind those of energy planning and have rarely looked beyond the narrow benefits of strict water savings.

However, such narrow planning methods can severely understate the overall societal benefits which can be achieved through resource conservation. Water conservation provides benefits not only through savings to the water utility, but also through reduced wastewater treatment and disposal requirements and through reduced energy consumption.

This paper summarizes the methodology and results of a comprehensive study performed in the Sacramento, California area looking in detail at combined water, wastewater, and energy savings achievable through end-use water conservation. Energy benefits are analyzed which accrue not only through reductions in hot water usage (low-flow showerheads, etc.), but also through reduced pumping and treatment requirements at water and wastewater treatment and conveyance facilities.

Energy consumption of water and wastewater facilities per unit of flow is analyzed and characterized into flow-related and non-flow-related energy. Water conservation technologies are examined, and benefits of end-use water conservation are analyzed using a computer model from the perspective of overall society and from individual water, wastewater, and electric utility perspectives.

Introduction

The State of California experienced six consecutive years of drought from the mid 1980s through the early 1990s. In the Sacramento area, this period of low precipitation coincided with a time of rapid economic and population growth, causing concern about the area's future water resources. At the same time, the advent of the concept of integrated resource planning has encouraged a new planning framework which accounts for multi-resource interactions and multi-agency cooperation.

In response to these developments, the Sacramento Alliance for the Conservation of Water and Energy Together (Alliance) was formed in February, 1990. The Alliance is composed of the Sacramento Municipal Utility

District (electricity), the City of Sacramento (water), and the Sacramento Regional County Sanitation District (wastewater). Its mission is promote end-use water conservation with conjunctive wastewater and energy savings as a strategy to provide reliable water, wastewater, and energy services at the lowest possible cost with the least impact to the environment.

This paper outlines the Alliance's first comprehensive analysis of joint water, wastewater, and energy conservation potential in the Sacramento, California area. Analysis methodologies and results, including cost-effectiveness to each agency, are highlighted.

Study Methodology

The study involved three primary areas of analysis: market and technology analysis; development of avoided water and wastewater operations and maintenance (O&M) cost figures (including facility energy use); and development of capital costs for water and wastewater facilities avoidable through water conservation. The results of these three processes were then combined to perform benefit/cost analyses through a computer model for more than 100 technologies and market segments by comparing the measures' costs and water/wastewater/energy savings with the utilities' avoided costs. Lastly, cost-effective measures were aggregated into an overall conservation plan. Figure 1 provides a project overview. Each task area is described in further detail below.

Market and Technology Analysis

Market Segmentation. Baseline water use and wastewater flow patterns were first analyzed to determine which market segments were creating large demands on the Alliant system. The study particularly emphasized analysis of the commercial and industrial sectors, though the residential sector was studied as well. Agricultural water use was not included in the analysis. Based on the flow analysis, the overall Alliance market was divided into the

following nineteen segments for targeting of conservation measures: *Residential:* Multi Family, Single Family; *Commercial:* Car Wash, Commercial Laundry, Education, Grocery, Health Care, Hotels and Motels, Miscellaneous, Offices, Restaurants, Retail Stores, and Warehouses; *Industrial:* Beverage Bottling, Dairy, Food Processing, Industrial Laundry, Metal Plating, and Miscellaneous.

Almost 75 percent of urban water use (i.e., not including agriculture) in the Sacramento area is residential. As a result, though this study was more detailed in the commercial and industrial sectors, the bulk of potential water savings is in the residential sector.

Technology Options. Potential water conservation measures were identified for each of the nineteen market segments. Technologies were characterized into four primary areas: cooling, process, domestic, and landscaping. A detailed literature review was conducted regarding available technologies and their potential water savings, particularly for cooling and process applications. Cooling measures fall into two primary categories: closure of single-pass cooling loops through installation of cooling towers, and increase of cooling tower concentration ratios through improved chemical treatment. Domestic plumbing measures studied include ultra low flow toilets, faucet aerators, low flow showerheads, and toilet fill cycle regulators. Domestic plumbing DSM measures are largely

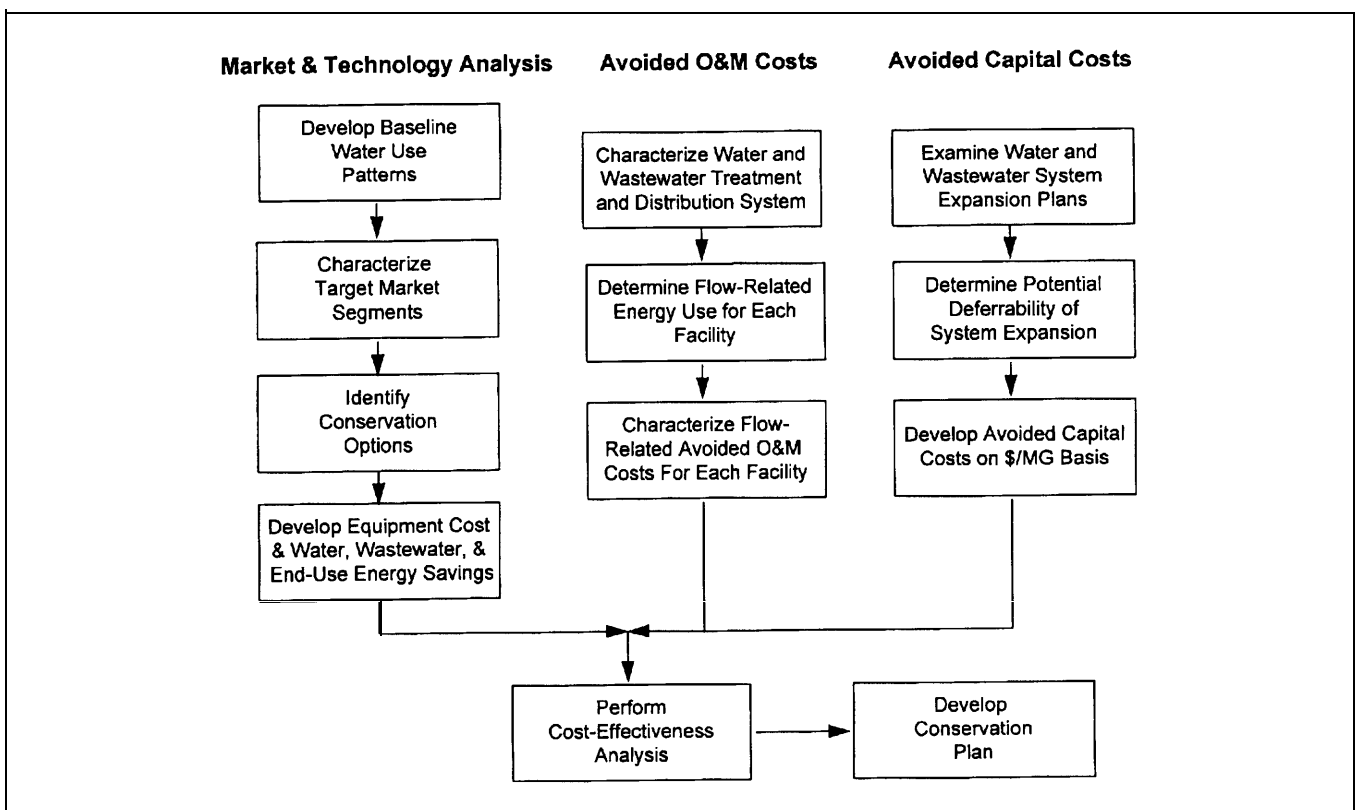


Figure 1. Study Flow Chart

applicable only to retrofits of existing facilities in California, however, as efficient plumbing fixtures are now required by state law for new construction. Landscaping measures include irrigation scheduling, drip irrigation, low water use landscaping, soil moisture sensors, and several others.

Industrial process water conservation measures are highly site-specific but can generally be described in the following categories: process water recycling, high-pressure low-volume rinsing systems, counter-current product rinsing, plant cleaning operation changes, installation of water valves and timers, and leak repair. For example, conservation measures in a beverage bottling facility might include recycling of filter backwash water; recovery of pump seal water; dry line can conveying systems; electrical heat tape around CO₂ piping to eliminate thaw water; high pressure-low flow hose nozzles and pumps for washdown; photoelectric control switch installation on can, bottle, and tray washer sprays (San Buenaventura, 1992; MWRA, 1989).

The costs of implementing each measure and the potential water and wastewater savings were analyzed for each technology in each market segment. Analysis of energy savings is more complex because energy reductions must be differentiated between those occurring at the end-user's site and those occurring at water/wastewater system facilities from reduced pumping. This differentiation is necessary because energy savings at the end-user's site (i.e., hot water savings) will accrue to the customer and will influence his or her decision to implement the conserving technology. Energy savings at water system facilities will accrue only to the utility and will not influence customer decision making.

Energy savings were therefore analyzed in two ways: 1) Hot water savings occurring at the customer site were characterized as either gas or electric savings (based on relative saturations of gas vs. electric water heating equipment) and accrued to both the customer (as energy bill savings) and to the energy utility (as avoided costs); and 2) The electric utility also accrued benefits through reduced pumping and treatment requirements in the treatment and conveyance systems for both hot and cold water conserving devices. Cold water savings would not provide any energy benefits at the end-user's site, however. Derivation of avoided energy and O&M costs in the water and wastewater system is described below.

Avoided O&M Costs

In order to determine the energy use in the water and wastewater system that can be avoided through end-use water conservation, it was first necessary to characterize the flow-related energy use of all major water and

wastewater treatment and conveyance facilities in the Alliance study area and then to develop a flow-weighted average energy use per million gallons of flow. Differentiating between flow-related and non-flow-related energy was difficult, however, due to lack of data over a variety of flow conditions.

For potable water treatment and distribution facilities, energy use is strongly correlated to varying monthly water flow, allowing straightforward linear regression analysis for determination of flow-related energy use. For wastewater facilities, however, the relationship between flow and energy use is much less clear, as a substantial portion of wastewater treatment plant energy use is due to non-flow-related factors such as sewage strength and solids loadings. In addition, wastewater flows in the Sacramento area are highly consistent throughout the year, resulting in highly grouped data and making linear regression analysis unreliable. Figure 2 shows a plot of energy use versus flow for a water treatment plant and wastewater treatment plant in the Alliance study area.

The water treatment plant plot shows a clear relationship between energy use and flow, and the steep slope represents high flow-related energy use. The wastewater treatment plant data shows virtually no scatter, reducing the validity of the regression analysis. Site visits and pump tests were therefore necessary for the wastewater facilities. The lesser slope of the wastewater plot, however, does suggest a lower flow-related energy use than for water facilities. In general, wastewater treatment facilities can be highly energy-intensive, but the amount of energy use which can be avoided through flow reduction is less for wastewater plants than for water facilities.

Energy is only one component of O&M costs which may be avoided through water use reductions. Certain chemical and labor costs are also related to flow and may be avoided through water conservation. Again, determination of the proportion of costs which are flow-related is difficult, particularly for labor costs which are largely fixed. General non-energy and non-chemical O&M costs were assumed to be only 10 percent deferrable through water use reductions. Upon determination of flow-related energy, chemical, labor, and other O&M costs for each facility, these costs were weighted by flow through each facility to develop overall water and wastewater O&M benefits (or avoided O&M costs) for the water agency, wastewater agency, and electric utility on a dollars per million gallons (\$/MG) basis.

Avoided Capital Costs

Avoided capital costs (i.e., capital expenditures which can be avoided through flow reductions) were developed by apportioning expected future capacity construction

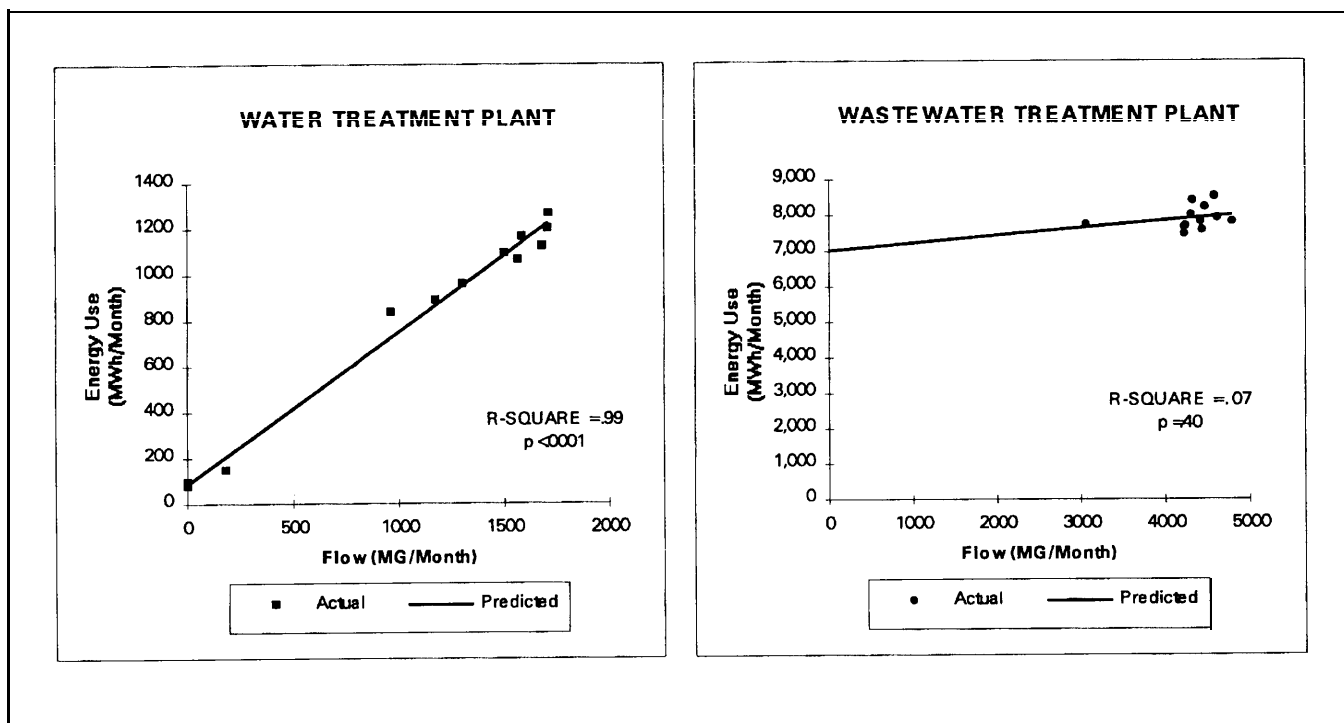


Figure 2. Sample Regression Results for Determination of Flow-Related Energy Use

expenditures over incremental flow increases. For wastewater systems, only 50 percent of planned capacity increases were assumed to be potentially deferrable due to water conservation. The remaining 50 percent were considered non-deferrable due to water quality and wet weather flow considerations. Potable water system capacity expansion was considered 100 percent potentially deferrable. Avoided capital costs were combined with the avoided O&M costs highlighted above to develop overall avoided water and wastewater costs. These avoided costs represent the benefits of water conservation to the utilities and to society and were used in the benefit/cost analysis of determine conservation cost-effectiveness.

Study Results

Results of the avoided cost analysis are presented here, followed by cost-effectiveness results and overall potential savings estimates.

Benefits to Water, Wastewater, and Electric Utilities

Potable water avoided capital costs were developed by apportioning the expected 360 million gallons per day (MGD) of additional flow through the year 2021 into water system expansion costs of \$380 million (present value). Capital costs were allocated on a yearly basis, resulting in a water avoided capital cost of \$553/MG in 1992. For the wastewater system, incremental wet weather

flow of 301 MGD through 2021 was apportioned into \$450 million (present value) of potential avoided expansion costs to develop an avoided wastewater capital cost of \$666/MG in 1992. Avoided capacity costs (i.e., capital expenditure reduction benefits) were therefore determined to be higher for wastewater systems than for water systems even though it was assumed that only 50 percent of wastewater capital expenditures were potentially deferrable through conservation (as outlined above), compared to 100 percent of water capital expenditures.

Flow-related energy use, or the energy savings which can be achieved in the water/wastewater system through end-use water conservation, was determined to be 787 kWh/MG for the water system and 385 kWh/MG for the wastewater system. The water system has considerably higher flow-related energy use than the wastewater system, though the wastewater system uses more energy in total. These energy savings achieved through water conservation translate into cost savings for the water, wastewater, and energy agencies, though the calculation of benefits differs based on each agency's perspective. The water and wastewater agency savings reflect energy tariffs charged by the electric utility, while the electric utility savings reflect marginal energy and capacity costs. Table 1 provides a breakdown of the avoided costs realized by each agency as well as by society as a whole.

Two items are particularly noteworthy in Table 1. First, the wastewater agency realizes savings even greater than the water agency because the wastewater agency's

Table 1. Water Conservation Avoided Costs

Perspective	Operations and Maintenance Costs			Total O&M (\$/MG)	Capital Costs (\$/MG)	Total Costs (\$/MG)
	Chemical (\$/MG)	Other O&M (\$/MG)	Energy (\$/MG)			
Water Agency	8.33	11.92	47.50	67.74	553	621
Wastewater Agency	30.25	31.13	22.91	84.30	666	750
Electric Utility ^(a)	-	-	47.80	47.80	-	48
Overall Societal	38.58	43.05	47.80	129.43	1219	1348

(a) Electric utility savings shown are for cold water only.

per-gallon avoided costs are higher. Therefore, the common practice of ignoring sewage savings when analyzing water conservation programs may cause more than 50 percent of indoor conservation benefits to go uncounted. Incorporating avoided environmental impacts could further raise the benefits of reduced wastewater production. On the other hand, outdoor landscaping and irrigation measures would not generally flow to the sewer system and thus would not accrue the same wastewater benefits. The wastewater benefits of reduced outdoor water usage may still be substantial in the agricultural sector, however, by reducing agricultural drainage costs.

The second notable point in Table 1 is the relatively low avoided costs for the electric utility compared to the water and wastewater agencies. Based on the energy required to pump water and wastewater, the total benefits of water conservation to the electric utility are only \$48/MG, compared to \$621/MG and \$750/MG for the water and wastewater agencies, respectively. This is because, compared to the costs of constructing dedicated water and wastewater treatment and distribution systems, the cost of supplying energy for pumping is low in the Sacramento area (based on water/wastewater system total flow-related energy requirements of 1,172 kWh/MG and SMUD's melded avoided energy and capacity cost of 4.08 cents per kWh in 1992).

The discrepancy between the water and wastewater agencies' avoided costs and those of the electric utility may not be as great in other geographical locations, however. Because the Sacramento area is characterized by flat land and a nearby water source, pumping energy required by the water system is expected to be particularly low. At the

other extreme, Southern California areas receiving water from the State Water Project, which is pumped over the Tehachapi Mountains, use a significant amount of energy for pumping. A study of Southern California's flow-related energy requirements would be quite complex, however, involving multiple pump stations, hydroelectric power plants, and analysis of water flow from as far away as Lake Shasta near the Oregon border.

It should also be noted that the avoided energy costs shown in Table 1 are for cold (unheated) water only, representing energy reductions within the water and wastewater treatment and conveyance systems. When hot water savings at the end-user's site are considered, the avoided energy benefits become substantial. Assuming a hot water temperature of 120°F, an inlet temperature of 65°F, and an electric resistance water heater efficiency of 0.90, SMUD's 1992 avoided cost for electrically heated water was \$6,093/MG. Even given that only 14 percent of water heaters in the Sacramento area are electric, SMUD's avoided cost for hot water savings is still \$871/MG, higher than for both the water and wastewater agencies.

Benefit/Cost Analysis Results

All water conservation measures passing the Total Resource Cost (TRC) test from a societal perspective (combined water, wastewater, and energy benefits) were aggregated into an overall conservation plan. The benefit/cost results provide some interesting insights on the importance of multi-resource planning and are summarized in the following two scenarios.

Scenario 1: No ULF Toilets. An ultra low flow (ULF) toilet give-away program was modeled for the residential single and multi family markets but was not found to be cost-effective and was not included in the overall conservation plan. Of the remaining measures, aggregating all residential, commercial, and industrial measures which were cost-effective from an overall combined water, wastewater, and energy perspective resulted in an average annual water savings of 7.8 MGD during the 15 year life of the conservation plan. Aggregating those measures which were cost-effective from a water-only perspective (no wastewater or energy benefits) resulted in an average savings of 7.5 MGD.

In this case, the difference between cost-effective water savings from the two perspectives (overall societal and water-only) was small (0.3 MGD) since most measures which were cost-effective from the overall perspective were attractive enough to also be cost-effective from a water-only perspective. Therefore, the amount of cost-effective water savings may not always be strongly impacted by whether or not a multi-resource planning methodology is adopted. However, the net present value (NPV) of the overall multi-resource perspective was \$69 million, while that of the water-only perspective was only \$17 million, showing a significant difference in economic benefits from using the two different methodologies.

Scenario 2: Packaged Domestic Plumbing Measure. In this scenario, ULF toilets were packaged together with low-flow showerheads and faucet aerators as part of a domestic plumbing package rather than being promoted separately as in Scenario 1 above. In this case, the domestic plumbing package (including ULFs) was found to be cost-effective from the overall combined water, wastewater, and energy perspective but was not cost-effective from the water-only perspective. The domestic plumbing package therefore was included in the aggregate combined perspective plan but not in the water-only perspective plan. Because the residential ULF toilets obtain by far the largest savings of all measures in the Sacramento area, the water-only perspective (which did not contain the domestic plumbing measure) showed an average cost-effective savings level of only 5.4 MGD per year, while the combined perspective (including the domestic plumbing measure) resulted in an average cost-effective water savings level of 13.7 MGD. This highlights the very significant impact that a multi-resource planning methodology can have on savings level estimates if a program offering large savings is only marginally cost-effective. If a water conservation program had to be justified merely on the basis of water savings, the program would miss more than 8 MGD (equivalent to a mid-size water treatment plant) of additional savings that are cost-effective from an overall societal standpoint.

Energy Agency Benefits

From an electric-utility-only perspective, the total cost-effective savings was an average of 4.3 MGD per year. The vast bulk of these savings resulted from measures such as low-flow showerheads and faucet aerators which save hot water since the cost-effective savings achievable through cold water pumping reductions alone were not found to be significant in the Sacramento area. The relative lack of industrial facilities in the area may have reduced the overall cost-effectiveness of the water conservation measures from the electric utility perspective since industrial facilities frequently have sizable water pumping and heating loads.

Gas utility savings were not analyzed in detail as part of this study, though gas avoided costs through reduced water heating were included in the overall societal perspective benefits. The preponderance of gas water heat in the Sacramento area is likely to have made hot-water conserving measures particularly attractive for gas utilities which were not included in the study.

Conclusions

The Sacramento Alliance water and energy conservation study is one of the first attempts in the country at a comprehensive multi-resource conservation plan. Benefits accrued by wastewater agencies through end-use water conservation were found to be even greater than benefits to water agencies for indoor measures. As a result, incorporating wastewater agency benefits into water conservation planning can more than double some programs' cost-effectiveness compared to analyzing water benefits alone.

Benefits of water conservation to the electric utility were analyzed both in terms of water heating reductions through end-use hot water saving measures and through pumping reductions at water and wastewater treatment and conveyance facilities. Energy benefits from pumping reductions were found to be relatively small in the Sacramento area compared to the benefits of avoided capital costs for water and wastewater facility construction. Avoided energy benefits may be considerably higher in areas which require significant pumping in their water systems, however. Energy savings from hot water reduction were found to be significant from the electric utility perspective. In general, though, water conservation measures were more cost-effective for the water and wastewater utilities than for the electric utility.

The differences in benefits accrued by each agency raises the issue of funding and how conservation program costs should be apportioned to each agency in a multi-agency

collaborative effort. Computer software has been developed that is capable of performing benefit/cost analyses of water conservation programs from the perspective of water, wastewater, electricity, and gas utilities as well as all utilities in combination. Costs can then be apportioned to each utility based on the benefits accruing to each agency as calculated using the Utility Test of the California Standard Practice Methodology benefit cost tests.

The problem can be further complicated by the fact that any multi-agency collaboration may include more than one water utility, wastewater utility, etc., each with their own pump stations, treatment facilities, and avoided costs. For this study, a simplifying assumption was made by combining all water agencies into one agency, though wastewater agency avoided costs were split between benefits accruing to the Sacramento Regional County Sanitation District and those accruing to other sewer agencies in the study area. The benefits of added detail available through agency disaggregation must be carefully balanced against the costs of resulting added analysis complexity.

The methodology for conducting such multi-resource, multi-agency analyses is still evolving, and further refinement is warranted. We hope that the Sacramento Alliance will be the first of many such collaborations to maximize resource planning efficacy as development pressures increase on the limited water resources of the western United States.

Acknowledgments

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