Relative Costs of New Water Supply Options for Front Range Cities

Phase 2 Report

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PHASE 2 REPORT

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TABLE OF CONTENTS

Relative Costs of New Water Supply Options for Front Range Cities: Phase 2 Report

Tables and Figures

I. Introduction

The following report is the second (and final) installment of a project examining the costs associated with meeting future M&I (municipal and industrial) water supplies along Colorado's Front Range. As summarized in the recently updated Statewide Water Supply Initiative (SWSI 2010) reports, M&I water demand in Colorado is expected to climb by 600,000 to one million AF (AF) by 2050 (CWCB, 2010). Some mixture of three strategies will likely be necessary to meet this target: new water projects, water transfers (i.e., agricultural to urban reallocation), and conservation. Determining which option(s) is "best" is a complex matter that requires weighing highly case-specific opportunities, constraints, trade-offs, risks, uncertainties, and values. Presumably, among the most important considerations is economic cost. In this Phase 2 report, we continue our consideration of what is known and unknown about the economic costs of meeting these future water demands.

A. Review of Phase 1 Findings

In Phase 1, we provided rough cost estimates for each of the three types of options identified above, with all estimates converted to cost/acre-foot ($/AF). Phase 1 yielded three major conclusions: First, we found that cost information is hard to find. Second, we found that the data that exist have a lot of deficiencies, and are calculated in different ways. And third, we found that, no matter how we looked at the data, conservation appeared to offer the cheapest option. Overall, our estimates of representative costs (in $/AF) were as follows: new projects, $16,200; water transfers, $14,000; and conservation, $5,200. The following tables (Tables 1, 2 and 3) provide some of the key information used to support these generalizations; for those seeking more information, a condensed version (i.e., omitting the appendix) of the Phase 1 report is included herein as Appendix A.

Table 1. Least-Cost Alternatives of Selected New Water Supply Projects (Proposed)			
Project: Option	**Firm Yield** (AF/year)	**Total Cost** (2010 dollars)	**Unit Cost** ($/AF)
NISP: Proposed 1	40,000	$458,900,100	$11,473
SMWSA: S. Platte Shared- Greeley	47,800	$789,856,800	$16,524
SMWSA: Arkansas Shared- Avondale	47,800	$877,490,700	$18,358
SDS: Alt 3	74,900	$1,301,211,600	$17,373
Average (4 projects)	**52,625**	**$856,864,800**	**$15,932**
Weighted Average (total costs/total yields)			**$16,282**
NISP is the Northern Integrated Supply Project (six variations providing 15 northern Front Range cities with a firm yield of approximately 40,000 AF); SMWSA is the South Metro Water Supply Authority master plan (15 variations providing 32,100 to 47,800 AF of firm yield to 13 water providers in the southern Denver-metro area); SDS is the Southern Delivery System (seven variations providing 37,900 to 74,900 AF to customers along the southern Front Range). Values above are for the least-cost variations of each proposed project. The SMWSA has both a northern and southern route; thus, two options are noted above.			

Table 2. Summary of Major Front Range Water Transfers: 1990-2009				
Year	**Number of Transactions**	**Total Yield** (AF)	**Total Price** (2010 dollars)	**Unit Cost** ($/AF)
Total	121	31,241	$342,050,782	$10,949
Sub-Total: 2005-2009	33	7,817	$109,405,124	**$13,996**

Table 3. Summary of Data from 22 Water Conservation Implementation Plans

All Programs	**Total Cost** (over planning horizon)	**Total Water Savings** (in AF, over planning horizon)	**Average Cost** ($/AF)
Total	$328,648,807	63,534	**$5,173**

Cities and Districts: Arapahoe County Water and Wastewater Authority, Aurora, Boulder, Brighton, Castle Pines North, Castle Rock, Centennial, Colorado Springs, Denver, East Larimer County, Evans, Fort Collins Loveland Water District, Firestone, Greeley, Left Hand Water District, Longmont, Fort Lupton, Northglenn, North Table Mountain, North Weld County, Parker Water and Sanitation District, and Windsor

As noted in the Phase 1 report, and reiterated by reviewers of that draft, the cost estimates provided feature several significant limitations. For example, the "new projects" estimate is limited to upfront capital costs and does not consider operational expenses, which are significant as the era of gravity-fed water projects is mostly over in this region; the estimate of water transfers does not consider "transactions costs" (e.g., court costs), the potential need for new storage associated with the transfer, and social impacts; and the water conservation estimates only reflect the upfront expenses born by the utility, and do not consider costs paid directly by the consumer (e.g., the consumer share of fixture replacement costs). Additionally, the cost estimates are highly region and case specific.

B. Focus of Phase 2

In this Phase 2 study, the goal has been to identify that sub-set of data and methodological issues that have been identified as most salient in interpreting the cost data presented in the

Phase 1 report. Using feedback from the water management community and others[1], and based on the authors' own assessment of the Phase 1 findings, it was determined that two issues in particular deserve greater attention:

- The ongoing operational costs (especially the energy costs) of water projects needs to be included in the assessment of new project costs
- The direct consumer costs of conservation strategies (e.g., for fixture replacements) needs to be included in the assessment of conservation costs[2]

These two issues are more closely related than may initially be evident, as one of the most-cited "solutions" to the problem of growing energy (operational) costs of providing water services is to avoid those costs entirely through conservation programs that negate (or at least reduce) the need for expanded water delivery infrastructure. As Wilkinson (2011 [in press]), notes: "The magnitude of energy requirements of water suggests that *failing* to include embedded energy in water and wastewater systems, and *failing* to incorporate energy saving derived from water efficiency improvements, would be a policy opportunity lost." While this report summarizes some of the literature and data associated with this line of thinking, our primary intent is not to directly critique that argument[3], but is to discuss some of the data and methodological issues associated with better understanding this economic relationship between energy, water, and conservation, and to discuss the opportunities and challenges of using this information in existing processes and forums of water resource decision-making.

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[1] Much of the feedback was triggered by a presentation of the report to the Colorado Water Institute Advisory Board (November 5, 2010). The report received widespread attention; for example, it was the subject of an invited keynote address at the Greater Gallatin Watershed Council meeting in Bozeman, Montana (January 27, 2011).

[2] This issue was singled out for more research in SWSI 2010 Appendix N:

> " More information regarding the economics of water conservation, particularly as compared to other alternatives for developing new water supplies, would assist local, regional, and statewide planning efforts. Many economic evaluations of conservation neglect to include all of the potential benefits and costs associated with reducing future demand. Incorporating triple bottom line economic analysis and other full cost accounting methods into the evaluation of conservation and new supply alternatives is an important future goal. For example, customer side costs (e.g. new indoor fixtures and more efficient landscaping) are not included in the cost estimates and without that contribution, these savings cannot occur. Similarly, benefits such as customers' lower water bills and reduced water treatment plant costs are also excluded." [p. 78]

[3] Perhaps the most direct articulation of this argument is provided in a CWCB-sponsored study entitled "Energy Conservation = Water Conservation," by Western Resource Advocates (WRA, 2009).

II. The Growing Body of Knowledge

A. The Energy Intensity (EI) of Providing Water Services

Nationally, a variety of recent studies have focused on the multi-faceted relationship between water and energy[4], including the energy intensity (EI) of water, which is defined by Wilkinson (2000) as “the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location.” As shown below in Figure 1 (from Wilkinson, 2000), several elements of the M&I water use “lifecycle” can entail significant energy demands.

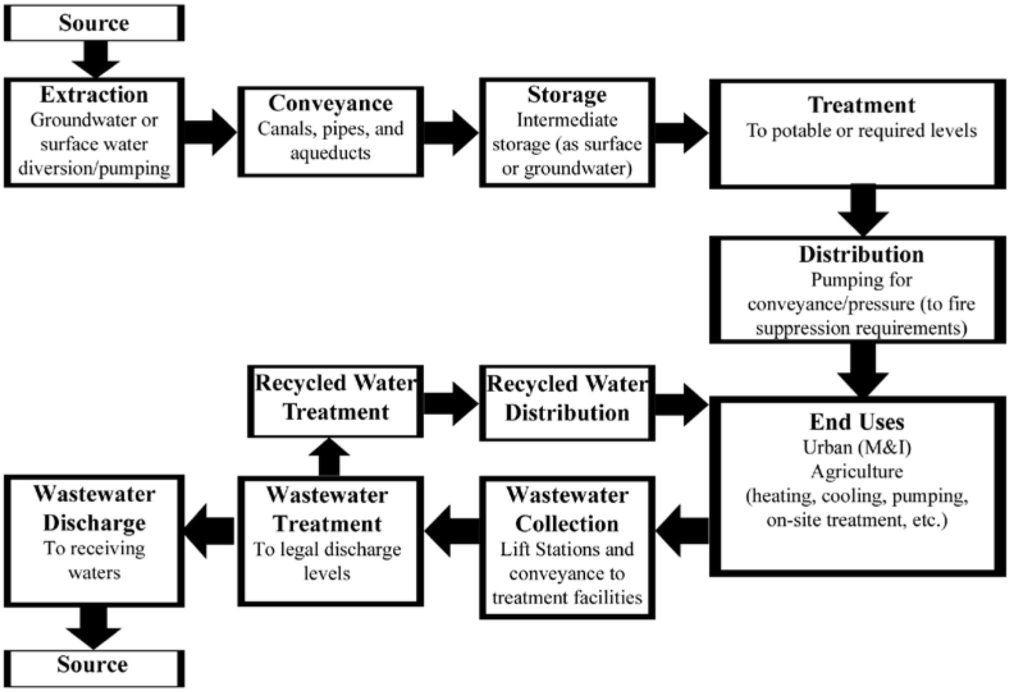

Figure 1. Energy Use in Water Systems

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[4] The author of this report recently co-edited a book entitled “The Water-Energy Nexus in the Western United States” (Kenney and Wilkinson, 2011 [in press]) that explores this theme in detail.

Much of the interest in EI comes from research in California, especially the 2005 report of the California Energy Commission (CEC, 2005), which found that water systems account for approximately 19 percent of the state's total electricity use, 33 percent of the non-powerplant natural gas use, and 88 million gallons of diesel consumption (CEC, 2005). These percentages are particularly high in California given the reliance of southern California on long-distance water conveyance systems (namely, the State Water Project and the All-American Canal). As Colorado increasingly considers long-distance pipeline projects, the California experience with EI may foreshadow our future.

Several themes permeate the EI literature, and three are particularly important. First, with the exception of some of the California research, data regarding the energy consumption of water management and use are difficult to obtain. As noted by the Government Accountability Office (GAO, 2011: 10), "[c]omprehensive data about the energy needed for each stage of the urban water lifecycle are limited, and few nationwide studies have been conducted on the amount of energy used to provide drinking water and wastewater treatment services to urban users." Second, to the extent that major investigations have been conducted, many of these studies (such as those of the Electric Power Research Institute) focus only on the "utility-centric" elements of water delivery and treatment, while omitting entirely energy associated with customer end-uses—typically the biggest contributor to overall EI (Cooley, 2010).[5] This shortcoming in the literature is telling, as it speaks to the issue, discussed later, of how the energy costs of water management are allocated between utilities and end-user. Finally, perhaps the most significant theme of this literature is that EI is increasing in almost all regions

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[5] End-user energy consumption is primarily associated with the heating of water for bathing, clothes washing, and cooking (and dish-washing); residential pump irrigation and water treatment systems can also be important in some regions (Cohen, 2004). State and federal governments have set appliance efficiency standards for toilets and some other household appliances, and in other cases manufacturers have simply moved to more efficient models due to market influences. However, the standards do not require the immediate replacement of inefficient versions. Accelerating this replacement through customer rebates or other incentives can undoubtedly save a lot of water and energy. For example, research by Western Resource Advocates (2009) estimates that if half of all Denver residents replaced inefficient showerheads, faucet aerators, faucets, clothes washers, and dishwashers with more efficient models, the water savings would total 19,100 AFY, while the total annual electricity savings would total 201,700 megawatt hours (including end use energy consumption).

and, in some places, this increase is dramatic.[6] As noted below, the Front Range of Colorado may be one of those places.

1. EI on Colorado's Front Range

The amount of energy needed by utilities to deliver and treat water for Front Range M&I users varies tremendously. Data compiled by Western Resource Advocates (WRA, 2009) (for the Colorado Water Conservation Board) show that most projects have EI values falling between 800 and 5,000 kWh/AF, with the low range associated with systems using clean snowmelt delivered through gravity-fed systems (e.g., Denver, Colorado Springs), and the higher values associated with relatively "dirty" water requiring extensive pumping (e.g., many south-metro communities) (WRA, 2009). Many of the newly proposed projects reliant on pipelines, such as the Southern Delivery System, fall toward the high end of this spectrum, which makes their EI comparable to saltwater desalination.[7]

One recent Colorado Water Conservation Board (CWCB) sponsored report attempts to integrate energy costs, and other ongoing operational expenses, into an analysis of this new breed of project costs. Appendix N ("Reconnaissance Level Cost Estimates for Strategy Concepts") of SWSI 2010 (CWCB, 2010) reviews seven "conceptual projects" capable of delivering 100-250 KAF to the Denver metro region. The Arkansas and South Platte projects (two alignments each) would convey agricultural water transfers, while three additional projects (the Blue Mesa, Flaming Gorge, and Yampa projects) would entail new diversions (i.e., "new projects"). These projects were first described in the 2009 CWCB report "Strategies for Colorado's Water Supply Future" (CWCB, 2009). The 100 KAF/year versions of these projects (the so-called "option 1" varieties) are described below.

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[6] Several location-specific factors make it difficult to generalize about EI values, including the type of water source involved, the topography and distance of the water transmission system, the quality of the water being treated (and the required treatment level and technology), the condition of the water system, and the nature of customer end-uses (GAO, 2011).

[7] Wilkinson (2011), in work for the California Desalination Task Force, estimated the energy requirements of ocean desalination at 4,400 kWh/AF. Tellinghuisen (2011) estimates the projected energy needs of the Southern Delivery System at 4,630 kWh/AF.

- Arkansas (alignment 1 and 2) = Alignment 1 conveys water from Avondale to Reuter-Hess Reservoir, while alignment 2 conveys water from La Junta to Reuter-Hess Reservoir.
- Blue Mesa = This project would move water from Blue Mesa Reservoir to Antero Reservoir (in the South Platte Basin).
- Flaming Gorge = This project would take water from Flaming Gorge reservoir and the Green River and convey it to Brighton.
- South Platte (alignment 1 and 2) = Alignment 1 conveys water from Greeley to Brighton, while alignment 2 conveys water from Prewitt Reservoir (near Sterling) to Brighton.
- Yampa = This project conveys water from the Maybell region to Brighton.

No attempt is made here to review or critique the full scope of Appendix N (which is available online[8]); the intent here is to show how a consideration of operating costs and the long-term costs of capital can radically modify initial cost estimates. As shown by data summarized below in Table 4, the upfront capital costs of the seven described projects were estimated to average $34,460/AF (when measured in terms of upfront utility costs). However, once the costs of capital are considered and the operational costs are considered, the full cost estimate (termed “total life cycle costs”) rises to an average of $83,329/AF—more than 2.4 times the original estimate.

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[8] http://cwcb.state.co.us/water-management/water-supply-planning/Pages/SWSI2010.aspx

Table 4. Summary of Cost Components for Selected “Option 1” Projects

	Ark. 1	Ark. 2	Blue Mesa	Flaming Gorge	South Platte 1	South Platte 2	Yampa	Average of 7 Projects
Upfront Capital Costs ($/AF)								
Total Capital Costs	31,300	35,000	24,540	39,540	33,000	36,900	40,940	34,460
Ongoing O&M (operation and maintenance) Costs ($/AF per year)								
Water Rights	4	4	4	4	4	4	4	4
Conveyance	540	620	600	550	130	290	550	469
Storage	2	2	2	2	2	2	2	2
Treatment	310	310	100	100	290	290	100	214
Reuse	190	190	190	190	190	190	190	190
Total Annual O&M	1,044	1,124	834	894	614	774	844	875
Life Cycle Costs ($/AF)								
Total Life Cycle Costs	93,500	100,700	76,600	81,800	67,900	80,300	82,500	83,329

O&M data is primarily derived from Table A-6 and A-7 of “Appendix N: Reconnaissance Level Cost Estimates for Strategy Concepts”; capital cost data are derived from Table A-1 and Figure 3-2; total life cycle costs are from A-9 and 3-7 (CWCB, 2010). Slight discrepancies on totals are a function of rounding errors. Note that several tables from Appendix N offer greater details regarding costs and their allocation; however, data discrepancies between tables limit their utility.

B. The Cost of Conservation

The CWCB has funded several major water conservation investigations in recent years, most notably as part of the Statewide Water Supply Initiative reports (in 2004, 2007, and 2010), and the conservation “guidebook” (i.e., the *Guidebook of Best Practices for Municipal Water Conservation in Colorado* produced by Colorado WaterWise in conjunction with the CWCB). One of the most useful analyses is SWSI 2010 Appendix L (CWCB, 2011), which provides a thorough overview of the numerous factors that must be considered when considering the viability of implementing conservation measures. Some of those factors include population levels; the mix of housing types; the “natural” replacement rate of existing water-using fixtures; the impact of past (completed) conservation programs; the interaction of various federal, state, and local programs; landscape preferences; technological improvements; and so on. Despite the report’s common refrain that “[l]imitations in availability and transparency of water use data continue to be one of the biggest challenges in advancing water conservation,” the reports commissioned by the CWCB provide an impressive assemblage of data and ideas, and the sophistication of methodologies used to estimate potential water savings is increasing rapidly (CWCB, 2011:33).

For the most part, the purpose of the CWCB conservation investigations has been to investigate the magnitude of the potential contribution that conservation can make toward meeting projected water supply gaps. Each report varies somewhat with respect to assumptions, the delineation of scenarios (e.g., levels of conservation), planning horizons (2030 or 2050), and other related factors; but all reports are consistent in showing significant potential savings. For example, SWSI 2010, Appendix L (CWCB, 2011: 10) concludes:

> If successfully implemented to the levels described, in 2050 the Low strategy + passive savings results in estimated statewide water savings of 314,200 AF. In 2050 the Medium strategy + passive savings results in estimated statewide water savings of 485,200 AF and the High strategy + passive savings results in estimated statewide water savings of 615,300 AF.[9]

To a lesser extent, several of these reports have also made an attempt to estimate the costs of various conservation efforts, again based on a variety of different assumptions. Both SWSI Phase 2 and SWSI 2010 estimate costs of "active conservation" in the neighborhood of $10,600/AF, while "passive savings" are estimated as being free ($0/AF).[10] The average "programmatic" cost, thus, is largely a function of the mix of active and passive efforts, which is largely a function of the penetration level of the conservation programs (as defined by the Low, Medium and High Strategies in the most recent CWCB-sponsored investigations).[11] The

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[9] Note that when compared to SWSI Phase 1 and SWSI Phase 2 estimates, the potential conservation savings estimated in SWSI 2010 are lower, largely because of conservation savings that have already been implemented in recent years. Statewide gcpd (gallons per capita per day) consumption has dropped 18 percent since publication of SWSI Phase 1 (CWCB, 2011).

[10] "Passive" conservation is simply the savings associated with the natural replacement of outdated water-use fixtures, in part prompted by updated building code standards and fixture performance standards established by federal laws such as the US Energy Policy Act of 1992.

[11] Using the SWSI 2010 methodology, estimated utility-side costs are as follows: "$5,358 per AF of savings for the Low strategy, $7,296 per AF of savings for the Medium strategy, and $8,183 per AF of savings for the High strategy" (CWCB Appendix L, 2011:12). As noted earlier (and presented in Appendix A), the programs reviewed in Phase 1 of this investigation (Kenney et al., 2010), featured an average cost of $5,200.

definition of scenario greatly shapes the cost estimates; essentially, the choice of scenario can suggest large potential water savings at relatively high per-unit cost, or low potential water savings at very low cost.

Despite these areas of progress, the cost estimates generated thus far are still limited to the expenditures incurred by the implementing utility. As noted in SWSI 2010, Appendix L (CWCB, 2011:12), "[c]ustomer side costs [for the conservation measures] were not included because, as with all other SWSI 2010 supply strategies (i.e. agricultural transfers and new supply projects), only the direct utility costs for implementing conservation were considered. Water users must ultimately bear the costs of all new water supplies, but consideration of the customer side costs for conservation implementation was beyond the scope of this effort." Similarly, cost estimates typically do not fully consider all benefits. While this is common shortcoming, it is a significant lost opportunity—as noted by Wilkinson (2011 [*in press*]):

> When the costs and benefits of a proposed policy or action are analyzed, we typically focus on accounting for costs, and then we compare those costs with a specific, well-defined benefit such as an additional increment of water or energy supply. We often fail to account for other important benefits that accrue from well-planned investments that address multiple objectives. With a focus on *multiple benefits*, we account for various goals achieved through a single investment. For example, improvements in water-use efficiency—meeting the same end-use needs with less water—also typically provide related benefits such as reduced energy requirements for water pumping and treatment (with reduced pollution and greenhouse gas emissions related to energy production as a result), and reduced water and wastewater infrastructure capacity (capital costs) and processing (operating costs) requirements. Impacts caused by extraction of source water from surface or groundwater systems are also reduced. Water managers often do not receive credit for providing these multiple benefits when they implement water efficiency, recharge and reuse strategies. From an investment perspective, and from the standpoint of public

policy, the multiple benefits of efficiency improvements and recharge and reuse should be fully included in cost/benefit analysis.

III. Toward Improved Cost Accounting

While acquiring additional data regarding water development and conservation options remains a research priority, the more formidable challenge moving forward may be to devise practical methodologies for organizing and utilizing the growing body of data in a way that informs a meaningful consideration of economic costs. Specifically, there remains a need for methodologies and processes that facilitate the presentation and consideration of economic data at the project/program-specific scale where water supply investments are made. For the Front Range—the primary focus of this investigation—the key decision-makers (in most cases) are municipal water agencies and any city councils, water boards, and so on, that might have some degree of oversight responsibility for those agencies. At this scale, not only is cost-related data associated with water supply options often not publicly accessible (as articulated in the Phase 1 report (Kenney et al., 2010)), it is unclear how (or if[12]) this data is considered internally. And, as noted earlier, to the extent that these cost estimates have been compiled, they are limited to utility costs and, in many cases, may unduly emphasize upfront expenditures while ignoring long-term costs associated with operations, avoided costs, and/or other economic considerations, including social and environmental impacts.[13] In short, sophisticated "full cost accounting" is a persistent deficiency in much of Colorado's water planning, and is a problem

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[12] One recent situation was described by Denver Post reporter Karen Crummy, who reported that the Arapahoe County Water and Wastewater Authority is building a $14 million reservoir without apparently conducting a costs analysis. "*Arapahoe County water project skipped over usual studies of cost, need.*" April 25, 2011. http://www.denverpost.com/search/ci_17921296

[13] The inherent deficiencies associated with the cost-recovery accounting that characterizes public water utilities was mentioned briefly in the Phase 1 report and is only briefly mentioned again here in Phase 2 as it is an issue that has been covered extensively by others, and is an issue that speaks more to "how to make decisions" rather than the challenge of compiling the data upon which decisions can be informed—the narrower focus of this study. In a nutshell, the economics literature shows cost-recovery accounting as being inconsistent with several economic principles associated with pricing scarce resources. For more information, see discussions by Howe (2005), Moncur and Pollock (1988), Griffin (2001), and Martin et al. (1984), among many others, regarding scarcity rent, marginal-cost pricing, and related topics.

that will not only require improved data collection, but improved tools and regulations for considering this information in decision-making.

A. Proposed Accounting Framework

A variety of methodologies have been (and continue to be) used to estimate costs of water projects. In fact, especially at the scale of federally funded projects, there is a colorful history of "creative accounting" practices pioneered in this sector designed to favor some (while disfavoring other) public policy choices. That history is not revisited here, except to observe that the way costs are tallied does have policy significance. In the following pages, a largely conceptual accounting framework is constructed and applied to highlight three policy considerations:

1. The need to consider operating costs (associated both with energy consumption and maintenance needs) when evaluating water supply options is growing, as the types and complexity of projects increases, their energy intensity is growing, and as the selection of options entails increasingly diverse "types" of projects (i.e., new developments versus transfers versus conservation)
2. As consumers are increasingly asked to directly bear upfront costs for some options (namely fixture retrofits), the need exists to ensure that these costs get tallied along with the "traditional" utility-born expenses in order to get an accurate accounting of total costs
3. The relationship between utility-born and consumer-born costs needs to be understood in order to ensure that decision-making processes accurately match decision-making incentives to the most relevant economic statistics

As summarized below in Table 5, the conceptual accounting framework presented requires the tabulation of data in cells A-I, where cell I (Total Costs) is offered as the appropriate economic metric for assessing relative costs. The accounting approach used is inspired by cost accounting, a subset of management accounting, with values tabulated in a modified balance sheet with values expressed as an annual cash flow needed to achieve a specified objective—in this case, the provision of an AF of water service, or in the case of conservation efforts, an AF worth of water *services*.[14] Long-term debt (for financing capital expenditures) is expressed simply in terms of an annual expense (current liability), calculated as a fixed value using a standard amortization table based on assumptions (specified later) regarding interest rates and terms. No effort is made to depreciate the assets (projects), as all are expected to be maintained in perpetuity and never resold. As is typical of most balance sheets, the framework features several "accounts" (i.e., cells A through I), many of which are defined as a sum of other accounts, with every transaction effecting at least two accounts (i.e., double-entry accounting).

Note that no attempt is made to match this project/program cost accounting with a determination of the economic benefits associated with the water service; thus, there is no way to use this approach to determine if a given project/program *should* be pursued. Rather, the purpose is to make more meaningful relative comparisons about the cost-effectiveness of different strategies for meeting projected water demands.

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[14] In applying the proposed accounting methodology of relative costs, it is important to appreciate that, if improperly structured, the conservation alternative could be inherently favored, as it is always cheaper (from the standpoint of the consumer (cell H)) to consume (and pay for) less water. Of course, that approach would be fundamentally flawed; while using no water would reduce consumer costs to zero, it would deprive the consumer from the water services that he/she expects, values, and is willing to pay for. Consequently, for purposes of the following examples, the operating assumption is that the consumer in all scenarios continues to receive the same level of *water-related benefits*, even if the level of *water consumption* is different.

Table 5. Conceptual Framework for Relative Costs Accounting

		Utility	Consumer
Annual Costs	Capital-Related Costs	A = Utility Capital Costs	B = Consumer Capital Costs
	Other Costs	C = Utility O&M Costs	D = Consumer Water-Use Costs
Annual Revenues	Income	E = Utility Income	F = Consumer Income
ANNUAL TOTALS		G = Net Utility Profit/Loss	H = Net Direct Consumer Costs
COMBINED ANNUAL TOTALS		I = Total Costs	

A = Utility Capital Costs. This is a measure of upfront capital expenditures born by the utility (e.g., as presented in the Phase 1 report), often financed through a municipal bond. For purposes of analysis, this value should be presented in terms of an annual expense, which requires data/assumptions regarding the payback period (years) and interest rate (or, if outside financing is not utilized, some measure of the value of capital allocated to this project).

B = Consumer Capital Costs. This is a measure of upfront capital expenditures born directly by the consumer. This value can be significant for end-user conservation projects; otherwise, this value is typically zero. For comparative purposes, this value should also be presented in terms of an annual expense, likely using the same assumptions as item A.

C = Utility O&M Costs. This is primarily a measure of (a) energy costs (associated with water conveyance, treatment, delivery, and post-use treatment, but not direct end-user expenses), and (b) system maintenance. Some administrative costs may also be relevant.

D = Consumer Water-Use Costs. This value is best estimated by the customer's water bill, which is normally assumed to be equivalent to Item E (utility revenue). If water is used in an application requiring heating, end-user energy costs should also be included. Since the value of item D is normally identical to item E, these items offset in calculations of Total Costs (Item I), meaning that these assumptions are not important in showing total costs. Showing these values is only done to help convey the relationship between utility and consumer perspectives toward costs.

E = Utility Income. This value reflects the payments received from end-users (customers) (Item D). In a not-for-profit public utility, the water bill is primarily based on a consideration of utility capital costs (A) and operational expenses (C). Therefore, E is typically, by design, the sum of A+C; if not, the difference is expressed in Item G as a loss.

F = Consumer Income. In most cases, this value is zero; the main exception is customer rebates for retrofits (e.g., for toilets, washing machines, landscape replacements, and so on).

G = Net Utility Profit/Loss. This is the sum of assets and liabilities (A, C and E). For non-profit utilities (the dominant model in the US), this value is zero for water provided under cost-recovery budgeting. A negative value indicates a revenue deficiency associated with the program/project that must be offset by additional customer charges.

H = Net Direct Consumer Costs. This is the sum of expenditures (minus any revenues or savings) directly paid by the consumer for the specified level of service (B, D and F).

I = Total Costs. This is the sum of total costs that are, ultimately, paid by the consumer, either directly (H) or indirectly (G). In principle, this is the key value that should be used as the basis for meaningful comparative costs among water supply options.

B. Application

Conceptually, the approach described in Table 5 is a manageable accounting exercise; however, in practice, it is difficult to undertake such an activity without encountering formidable data needs, without making multiple (debatable) assumptions, and without confronting difficult issues about how cost information should be balanced with other information, such as customer and utility preferences. As such, the accounting approach as applied in Tables 6-11 is offered as a compromise between the ideal and the practical, and is intended as only a first step on a pathway to a more sophisticated way of considering costs in choosing among water supply options. Additional refinements are undoubtedly needed (and welcomed), including an effort to instill a “triple bottom line” analysis which would require adding an assessment of environmental and social costs and benefits. Those efforts are beyond the scope of this effort.

The following tables (6-11) examine the total costs of new projects and indoor conservation projects based on fixture replacement (i.e., toilets and clothes washers). While these are “hypothetical” or conceptual in nature, they are based on data pulled from Front Range examples (many summarized in the Phase 1 report and in CWCB sponsored works) and the professional literature. *However, while these numbers are defensible, the primary intent here is merely to illustrate the potential decision-making value of a modified accounting methodology.*

The following tables describe an accounting of costs for three new project scenarios, two toilet replacement scenarios, and one clothes washer replacement scenario. The three “new project” scenarios trace those projects summarized in the Phase 1 report (Table 7), the sub-set of projects summarized earlier in Table 4 from SWSI Appendix N (Table 8), and a “blend” of those two compilations (in Table 6). The two toilet replacement scenarios trace costs associated with a $75 customer rebate (Table 9) and a $150 rebate (Table 10). Finally, the costs associated with a clothes washer rebate program (at the $100 level) are provided (Table 11). Data from all the scenarios is later compiled in a summary table (Table 12).

A few assumptions are common to each scenario, namely:

- Costs are shown on an annual basis. To do this requires selection of a planning horizon. For new projects, the planning horizon selected is 50 years, which is value used in SWSI 2010 Appendix N. For fixture replacements, the horizon selected is 10 years. This value is used to acknowledge that, in absence of a rebate program, these upgrades would eventually occur automatically through so-called “passive” conservation.
- Upfront capital costs (either paid by the utility or directly by the consumer) are assessed a six percent interest rate, the assumption used in SWSI 2010 Appendix N.
- Only the allocation of costs between the utility and the consumer are shown. However, costs and benefits to other sectors do accrue. For example, new projects provide construction industry benefits; fixture replacements provide hardware/plumbing industry benefits; energy-saving options modify costs/benefits to the electric industry; and so on. For policy-making, these other impacts may be worth considering, but are considered outside the scope of the methodology applied herein.

Assumptions that are specific to each scenario are noted in the tables themselves. We have been explicit in identifying assumptions with the intent of encouraging readers to change them as better data is acquired, or as new scenarios are developed for analysis.

<table>
<tr><th colspan="4">Table 6. Costs of New Projects ($/AFY) [Phase 1 and Selected Appendix N Options] ($/AFY)</th></tr>
<tr><td colspan="2"></td><td>Utility</td><td>Consumer</td></tr>
<tr><td rowspan="2"><i>Annual Costs</i></td><td>Capital-Related Costs</td><td>A = Utility Capital Costs
$1,600</td><td>B = Consumer Capital Costs
$0</td></tr>
<tr><td>Other Costs</td><td>C = Utility O&M Costs
$688</td><td>D = Consumer Water-Use Costs
$2,288</td></tr>
<tr><td><i>Annual Revenues</i></td><td>Income</td><td>E = Utility Income
(+$2,288) (credit)</td><td>F = Consumer Income
$0</td></tr>
<tr><td colspan="2"><i>ANNUAL TOTALS</i></td><td>G = Net Utility Profit/Loss
$0</td><td>H = Net Direct Consumer Costs
$2,288</td></tr>
<tr><td colspan="2"><i>COMBINED ANNUAL TOTALS</i></td><td colspan="2">I = Total Costs
$2,288</td></tr>
</table>

A = Utility Capital Costs. As noted earlier in Table 1, the projects reviewed in Phase 1 reported an average upfront utility capital cost of $16,200/AF (see Table 7); the sub-set of projects from SWSI 2010 Appendix N described earlier in Table 4 averaged $34,460/AF (see Table 8). For this exercise, we take the midpoint of this range ($25,330/AF), and amortize this to an annual expenditure ($1,600 AFY) (assuming six percent for 50 years).

B = Consumer Capital Costs. None of the capital costs are directly born by the consumer in this scenario, but are ultimately passed on in water bills (Item D) and/or taxes.

C = Utility O&M Costs. Developing annual utility-born operating costs require dozens of assumptions: energy needs vary largely based on water quality and elevation changes; maintenance costs are shaped by the type of project (e.g., uphill pipelines versus gravity-fed ditches) and maintenance schedules for various components; costs are shaped by discount rates, planning periods, electricity costs; and so on. The sub-set of projects described earlier in Table 4 from SWSI 2010 Appendix N estimate average annual O&M costs at $875. As noted on Table 7, the appropriate value for the Phase 1 projects is likely lower (estimated at $500). For this scenario, the midpoint value ($688) is utilized.

D = Consumer Water-Use Costs. Customer costs in this scenario are those associated with their water bill, which is crafted by the utility to exactly offset the costs in items A and C. Thus, for the purposes of our exercise: D = A + C. Water rates vary significantly from provider to provider, over time, and allocate expenses between variable volume-based charges and fixed charges. For purposes of context, if you were to assume that each AF annually serves, on average, two connections (households) each paying $15/month in fixed charges (total of $360/AFY), then this scenario would require an average volumetric charge (for water and wastewater) of $5.92/1,000 gallons to offset the utility costs. Note that for purposes of this scenario, we are assuming that the water provided is for end-user applications that do not require additional expenditures (such as heating costs). In other types of comparisons (e.g., see Table 11 regarding clothes washers), it might be useful to include customer-born energy expenditures/savings.

E = Utility Income. Equivalent to item D (funds collected from customer bills).

F = Consumer Income. No rebates or other customer revenue is associated with this scenario.

G = Net Utility Profit/Loss. This value is zero since all utility-born costs were passed on to customers in water bills (as is typical of public utilities).

H = Net Direct Consumer Costs. This is the sum of B, D and F.

I = Total Costs. Sum of G and H.

Table 7. Costs of New Projects ($/AFY) [Phase 1 Projects] ($/AFY)

		Utility	Consumer
Annual Costs	Capital-Related Costs	A = Utility Capital Costs $1,023	B = Consumer Capital Costs $0
	Other Costs	C = Utility O&M Costs $500	D = Consumer Water-Use Costs $1,523
Annual Revenues	Income	E = Utility Income (+$1,523) (credit)	F = Consumer Income $0
ANNUAL TOTALS		G = Net Utility Profit/Loss $0	H =Net Direct Consumer Costs $1,523
COMBINED ANNUAL TOTALS		I = Total Costs $1,523	

A = Utility Capital Costs. This scenario is based on the projects reviewed in Phase 1 (see Table 1), which reported an average upfront utility capital cost of $16,200/AF. This value has been amortized to an annual cost ($1,023 AFY).

B = Consumer Capital Costs. None of the capital costs are directly born by the consumer in this scenario, but are ultimately passed on in water bills (Item D) and/or taxes.

C = Utility O&M Costs. Annual O&M for the Phase 1 projects was not tabulated due to data deficiencies. From what data is available, however, it seems likely that the "real value" is likely to be significantly lower than the Appendix N projects described in Table 6 (where annual O&M costs are estimated at $875). For purposes of this scenario, a value of $500 is estimated. This is a very rough estimate, offered here mostly as a placeholder awaiting better data. (Some of these costs are discussed in WRA, 2009.)

D = Consumer Water-Use Costs. Customer costs in this scenario are those associated with their water bill, which is crafted by the utility to exactly offset the costs in items A and C. Using the same assumptions and methodology as described in Table 6, this scenario would translate to an average required volumetric charge (for water and wastewater) of $3.57/1,000 gallons.

E = Utility Income. Equivalent to item D (funds collected from customer bills).

F = Consumer Income. No rebates or other customer revenue is associated with this scenario.

G = Net Utility Profit/Loss. This value is zero since all utility-born costs were passed on to customers in water bills (as is typical of public utilities).

H = Net Direct Consumer Costs. This is the sum of B, D and F.

I = Total Costs. Sum of G and H.

Table 8. Costs of New Projects ($/AFY) [Selected Appendix N Projects] ($/AFY)

		Utility	Consumer
Annual Costs	Capital-Related Costs	A = Utility Capital Costs $2,177	B = Consumer Capital Costs $0
	Other Costs	C = Utility O&M Costs $875	D = Consumer Water-Use Costs $3,052
Annual Revenues	Income	E = Utility Income (+$3,052) (credit)	F = Consumer Income $0
ANNUAL TOTALS		G = Net Utility Profit/Loss $0	H = Net Direct Consumer Costs $3,052
COMBINED ANNUAL TOTALS		I = Total Costs $3,052	

A = Utility Capital Costs. This scenario is based on the sub-set of "Option 1" projects reviewed in SWSI 2010 Appendix N (see Table 4), which reported an average upfront utility capital cost of $34,460/AF. This value has been amortized to an annual cost ($2,177 AFY).

B = Consumer Capital Costs. None of the capital costs are directly born by the consumer in this scenario, but are ultimately passed on in water bills (Item D) and/or taxes.

C = Utility O&M Costs. SWSI 2010 Appendix N estimates the average annual O&M for those projects listed earlier in Table 4 at $875/AF. That value is used here.

D = Consumer Water-Use Costs. Customer costs in this scenario are those associated with their water bill, which is crafted by the utility to exactly offset the costs in items A and C. Using the same assumptions and methodology as shown in Table 6, this scenario would translate to an average required volumetric charge (for water and wastewater) of $8.26/1,000 gallons.

E = Utility Income. Equivalent to item D (funds collected from customer bills).

F = Consumer Income. No rebates or other customer revenue is associated with this scenario.

G = Net Utility Profit/Loss. This value is zero since all utility-born costs were passed on to customers in water bills (as is typical of public utilities).

H =Net Direct Consumer Costs. This is the sum of B, D and F.

I = Total Costs. Sum of G and H.

Table 9. Costs of Conservation ($75 Toilet Rebates) ($/AFY)

		Utility	Consumer
Annual Costs	Capital-Related Costs	A = Utility Capital Costs $340	B = Consumer Capital Costs $959
	Other Costs	C = Utility O&M Costs $0	D = Consumer Water-Use Costs $0
Annual Revenues	Income	E = Utility Income $0	F = Consumer Income (+$225) (credit)
ANNUAL TOTALS		G = Net Utility Profit/Loss $340	H = Net Direct Consumer Costs $734
COMBINED ANNUAL TOTALS		I = Total Costs $1,074	

A = Utility Capital Costs. The size of utility-offered rebates varies from city to city; a common value used by the largest municipalities (e.g., Denver, Colorado Springs, Aurora) is $75 per toilet. To convert this to $/AF, we need to estimate the water saved per replaced toilet, which is based on two factors: how much water is saved per flush, and how many times (in a given time period) a toilet is flushed. Both numbers are difficult to estimate with precision, and can vary according to many factors reviewed in great detail by Vickers (2010, chapter 2). Moderate- to high-volume toilets normally use somewhere between 3.5 to 7.0 gpf (gallons per flush), while low-flow toilets use 1.0 to 1.6 gpf. The typical residential toilet is flushed 13.5 times/day (based on 5.1 flushes/per by 2.64 users, as suggested by Vickers, 2010). Based on these rough parameters, and case studies in Los Angeles and Tampa, a reasonable assumption is that an upgraded toilet saves 30 gallons per day, which coincidentally translates to 30 toilet replacements to save 1 AF/year, costing the utility $,2,250 ($75*30). An additional $300 (raising the total to $2550) has been added ($10/toilet) to estimate one-time administrative costs of rebate processing; this estimate is not based on any available data, but is merely an estimate included here mostly as a placeholder awaiting better estimates. This value has been amortized to an annual cost ($340 AFY).

B = Consumer Capital Costs. Vickers (2010) estimates the upfront customer cost of a new toilet (including installation) at $240. This estimate is consistent with our interviews with local plumbing suppliers. Multiplying this by 30 (as explained under A) totals $7,200. This translates to an amortized cost of $959 AFY.

C = Utility O&M Costs. Since this scenario involves an AF of water that is not provided, there is no ongoing utility cost.

D = Consumer Water-Use Costs. Since this scenario involves an AF of water that is not consumed, there is no ongoing consumer cost.

E = Utility Income. Since this scenario involves an AF of water that is not provided, there is no unit-based revenue associated with a customer bill.

F = Consumer Income. This value, from A (before administrative costs), is money credited to consumers as rebates. This scenario assumes this full amount ($2,250) is rebated to customers over 10 years (or $225/year). Theoretically, since we are assuming an annual discount rate of six percent for money borrowed, we could assume a 6 percent annual growth in the value of rebated money over the planning period. This was not done, however, since rebates are presumably used immediately to offset the fixture purpose and are not retained by the customer.

G = Net Utility Profit/Loss. The sum of A, C and E. Since this value is a loss, it must be added to Net Direct Consumer Costs (H) in calculating Total Costs (I) since this cost will ultimately be passed along to the consumer.

H = Net Direct Consumer Costs. This is the sum of B, D, and F.

I = Total Costs. This is the sum of G and H.

Table 10. Costs of Conservation ($150 Toilet Rebates) ($/AFY)

		Utility	Consumer
Annual Costs	Capital-Related Costs	A = Utility Capital Costs $640	B = Consumer Capital Costs $959
	Other Costs	C = Utility O&M Costs $0	D = Consumer Water-Use Costs $0
Annual Revenues	Income	E = Utility Income $0	F = Consumer Income (+$450) (credit)
TOTALS		G = Net Utility Profit/Loss $640	H = Net Direct Consumer Costs $509
COMBINED TOTALS		I = Total Costs $1,149	

A = Utility Capital Costs. This scenario assumes a rebate of $150, which is the assumption used by the Conservation and Efficiency Technical Roundtable in SWSI Phase 2 (2007). All other assumptions are consistent with those outlined in Table 9. This results in the awarding of $4,500 in rebates (30*150) (per AF), or a total upfront utility capital expenditure of $4,800 assuming a $10/toilet rebate processing fee. This value has been amortized to an annual cost ($640 AFY).

B = Consumer Capital Costs. Vickers (2010) estimates the upfront customer cost of a new toilet (including installation) at $240. This estimate is consistent with our interviews with local plumbing suppliers. Multiplying this by 30 (as explained under A) totals $7,200. This translates to an amortized cost of $959 AFY.

C = Utility O&M Costs. Since this scenario involves an AF of water that is not provided, there is no ongoing utility cost.

D = Consumer Water-Use Costs. Since this scenario involves an AF of water that is not consumed, there is no ongoing consumer cost.

E = Utility Income. Since this scenario involves an AF of water that is not provided, there is no unit-based revenue associated with a customer bill.

F = Consumer Income. This value, from A (before administrative costs), is money credited to consumers as rebates. This scenario assumes this full amount ($4,500) is rebated to customers over 10 years (or $450/year). (See Table 9 for a more detailed explanation.)

G = Net Utility Profit/Loss. The sum of A, C and E. Since this value is a loss, it must be added to Net Direct Consumer Costs (H) in calculating Total Costs (I) since this cost will ultimately be passed along to the consumer.

H = Net Direct Consumer Costs. This is the sum of B, D, and F.

I = Total Costs. This is the sum of G and H.

Table 11. Costs of Conservation ($100 Washing Machine Rebates) ($/AFY)

		Utility	Consumer
Annual Costs	Capital-Related Costs	A = Utility Capital Costs $806	B = Consumer Capital Costs $5,862
	Other Costs	C = Utility O&M Costs $0	D = Consumer Water-use Costs (+$3,247) (credit)
Annual Revenues	Income	E = Utility Income $0	F = Consumer Income (+$550) (credit)
ANNUAL TOTALS		G = Net Utility Profit/Loss $806	H = Net Direct Consumer Costs $2,065
COMBINED ANNUAL TOTALS		I = Total Costs $2,871	

A = Utility Capital Costs. The size of utility-offered rebates varies from city to city; this scenario assumes rebates of $100 (as per Denver Water). As is true for toilet retrofits, the amount of water saved is a function of how often the appliance is used, and how much more efficient the new model is when compared to the old. Vickers (2010: 118) estimates annual (per machine) savings as ranging from 4,278 to 10,339 gallons. This translates to a need to replace 32 to 77 machines to save an AF. For purposes of our scenario, we have selected the midpoint (55 machines to save 1 AF). The rebates needed to save an AF are thus: 55*100 = $5,500. An additional $550 ($10/washer) has been added (raising the total to $6,050) to estimate one-time administrative costs of rebate processing; this estimate is not based on any available data, but is merely an estimate included here mostly as a placeholder awaiting better estimates. This value has been amortized to an annual cost ($806 AFY).

B = Consumer Capital Costs. Our review of local retailers suggests the upfront customer cost of a new clothes washer (including installation) to be $800. Multiplying this by 55 (as explained under A) totals $44,000. For consistency, as in Item A, this value has been amortized to an annual cost ($5,862 AFY).

C = Utility O&M Costs. Since this scenario involves an AF of water that is not provided, there is no ongoing utility O&M cost.

D = Consumer Water-Use Costs. Since this scenario involves an AF of water that is not consumed, there is no ongoing consumer cost. In this scenario, the customer is credited with an annual energy savings. Vickers (2010: 121) estimates annual (per machine) energy savings at 506 to 969 kWh per year. Taking the midpoint value (738 kWh/year), and multiplying this value by 55 machines, results in an end-use energy savings of 40,590 kWh/AFY. At energy costs of $0.08/kWh, this is an annual end-user energy savings of $3,247.

E = Utility Income. Since this scenario involves an AF of water that is not provided, there is no unit-based revenue associated with a customer bill.

F = Consumer Income. This value, from A (before administrative costs), is money credited to consumers as rebates. This scenario assumes this full amount ($5,500) is rebated to customers over 10 years (or $550/year). (See Table 9 for a more detailed explanation.)

G = Net Utility Profit/Loss. The sum of A, C and E. Since this value is a loss, it must be added to Net Direct Consumer Costs (H) in calculating Total Costs (I) since this cost will ultimately be passed along to the consumer.

H = Net Direct Consumer Costs. This is the sum of B, D, and F.

I = Total Costs. This is the sum of G and H.

1. Summary and Discussion

The data from Tables 6-11 is summarized below in Table 12.

Table 12. Summary of Scenarios ($/AFY)

Cost Category *	Scenario *					
	1	2	3	4	5	6
A	$1,600	$1,023	$2,177	$340	$640	$806
B	$0	$0	$0	$959	$959	$5,862
C	$688	$500	$875	$0	$0	$0
D	$2,288	$1,523	$3,052	$0	$0	(+$3,247)
E	(+$2,288)	(+$1,523)	(+$3,052)	$0	$0	$0
F	$0	$0	$0	(+$225)	(+$450)	(+$550)
G	$0	$0	$0	$340	$640	$806
H	$2,288	$1,523	$3,052	$734	$509	$2,065
I	$2,288	$1,523	$3,052	$1,074	$1,149	$2,871

* Scenarios: 1 = Phase 1 and Selected Appendix N Options (Table 6); 2 = Phase 1 Projects (Table 7); 3 = Selected Appendix N Projects (Table 8); 4 = $75 Toilet Rebates (Table 9); 5 = $150 Toilet Rebates (Table 10); 6 = $100 Washing Machine Rebates (Table 11).

* Cost Categories: A = Utility Capital Costs; B = Consumer Capital Costs; C = Utility O&M Costs; D = Consumer Water-Use Costs; E = Utility Income; F = Consumer Income; G = Net Utility Profit/Loss; H = Net Direct Consumer Costs; I = Total Costs. (See Table 5 for an explanation of terms.)

The data in Table 12 is useful to illustrate several points. First, while the accounting framework presented is primitive, it is important that no cost category is zero across all scenarios, suggesting that different "types" of scenarios raise very different issues regarding what constitutes accurate, full and policy relevant data. As noted earlier, the analysis in many reports (including Phase 1 of this study) is confined to a consideration of cost category A (Utility Capital Costs), which omits relevant energy and other O&M costs (now shown on line C) as well as direct consumer-born costs (shown on lines B and D). Without showing the ongoing costs in categories C and D, the high economic costs of new pipeline-centric water projects would remain hidden, while the overall (societal) economic benefits of washing machine rebates would be grossly understated. Similarly, without category B (Consumer Capital Costs), the true costs of conservation would be grossly overstated.

Particularly salient is the comparison of data on lines G (Net Utility Profit/Loss) and I (Total Costs). The comparison of lines G and I illustrate that, from the standpoint of the utility, the conservation options (scenarios 4-6) impose costs that are not directly offset by revenue from those consumers receiving the rebates, creating a revenue stream problem, and requiring the utility to offset those "revenue losses" by imposing additional fees on the full population of water users—causing the familiar citizen complaint of having rates raised in response to conservation successes. (This is handled in our framework by adding this deficient revenue stream—i.e., the negative value in category G—to the Direct Consumer Costs (item H) in order to reach the Total Costs value.)

Additionally, this comparison shows that the size of the fixture rebate is largely irrelevant in terms of the Total Cost (I), as the rebate only affects how the costs are initially allocated, and not the total expenditures involved. The modest change (roughly 7 percent) in Total Cost (from 1,074 to $1,149 AFY) in the $75 and $150 rebate scenarios (Tables 9 and 10) is entirely a function of borrowing costs. Should the utility not need to borrow money to implement the program—an entirely possible situation, especially at the lower ($75) rebate values, given the scale and phased-implementation of these types of rebate programs—then both would yield an identical Total Cost. Regardless of the rebate size, the fact remains that it takes, roughly, $7,200 worth of new toilets (given the assumptions provided) to save an AF of water, and that full cost is ultimately paid by the consumer in a combination of water bills and plumbing/hardware store expenditures. This illustrates an inherent drawback of making investment decisions through the lens of utility expenditures rather than the lens of total customer costs, as from the standpoint of the utility, the two programs look significantly different when, from the standpoint of the consumer, they are not.

Finally, returning to the approach used in the Phase 1 report of relying solely on upfront Utility Capital Costs (item A) as a surrogate for Total Costs (Item I), Table 12 does show that approach—with the exception of the washing machine rebate scenario (# 6)—to be generally appropriate for providing a rough economic *ranking* of alternatives. For example, the scenario with the highest upfront utility costs also features the highest total costs (scenario 3); similarly, the scenario with the lowest upfront utility costs also features the lowest total costs (scenario 4). However, for the reasons noted above, the upfront Utility Capital Costs approach is far from adequate in providing an accurate picture of overall costs[15], and it obscures many issues of great policy importance.

IV. Conclusions and Next Steps

Building on the findings in Phase 1, this Phase 2 confirms that a consideration of costs that is confined to upfront utility expenditures is an appropriate starting point of data collection and analysis, but by itself, is an inadequate basis on which to inform public policy decisions often involving billions of taxpayer dollars and the state's most important natural resource. To the extent that economic data is used to influence decisions on how to meet projected water supply gaps, two innovations are needed: (1) data and accounting methodologies that allow (a) a consideration of both capital and ongoing costs/benefits, and (b) a compilation of both utility-incurred and direct consumer-incurred costs/benefits integrated into an estimate of total costs; and (2) decision-making processes that ensure that this "total cost" metric is the primary economic criterion applied. These are very different challenges; the first is a methodological issue, while the second is a governance challenge raising issues about how utilities are financed and how (and by whom) decisions are made. While this report has focused on this first challenge, it is worth acknowledging that this second issue exists.[16] This subject is tangential to this Phase 2 report so is not explored further; the point is to merely reiterate that the key to achieving improved economic rationality in water supply decisions entails more than devising

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[15] It is important to again reiterate that the numbers summarized in Table 12 are primarily intended to illustrate a way of tabulating and comparing data in a policy-relevant manner; the validity of the numbers themselves can be debated, as they are based on a host of assumptions and generalizations.

[16] For example, it may be worth observing that, in Colorado, investor-owned utilities and some public utilities, such as those for energy (electric and gas), are subject to regulation by Public Utility Commissions (PUCs), which have an obligation to review financial data to ensure that consumers are served in a cost-effective manner, but public water utilities are outside of this framework. In California, public water agencies are subject to greater oversight, which can include mandated conservation requirements as well as efforts to integrate water and energy decisions. (See http://www.cpuc.ca.gov/PUC/Water/WaterSupplyCalifornia.htm.)

more detailed accounting methodologies, but also in modifying decision-making practices to require the application and use of those improved methodologies.

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Appendix A: Phase 1 Report [condensed] [originally published July, 2010]

(1) Introduction

Ensuring an adequate water supply for the growing population of Colorado's Front Range is an ongoing challenge for the water management community. In Colorado, the primary concern is satisfying the projected future water needs in the municipal and industrial (M&I) sector, especially along the populous Front Range. According to the (SWSI) studies overseen by the Colorado Water Conservation Board (CWCB, 2004), Colorado's population is projected to grow 65 percent between 2000 and 2030, resulting in an increasing M&I water demand of 630,000 AF.[17] The majority of this demand (507,700 AF) will occur along the Front Range in the South Platte and Arkansas Basins.

For the most part, each city and major suburb has its own water utility charged with the task of developing and managing the M&I (and sometimes agricultural) demands within its service area, often with little if any coordination with neighboring communities (and their water systems), and additionally, often with little meaningful integration with other city departments, including those making land-use and building decisions. As each city charts its own course in seeking to eliminate its own potential water supply gap, water utilities normally explore three general types of strategies: (1) increase water supplies through new projects (and/or the rehabilitation or expansion of existing projects); (2) purchase and transfer water rights from the agricultural sector; and/or (3) reduce demand through conservation and efficiency projects.[18] In the following pages, we review projects of each type on Colorado's Front Range, comparing the approaches based on one simple criterion: average cost per acre-foot ($/AF). As noted in the

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[17] Colorado Water Conservation Board. 2004. Statewide Water Supply Initiative. Colorado Department of Natural Resources.

[18] Of course, these options are not mutually exclusive; to the contrary, they can interact with each other in a variety of ways. For example, a decision to purchase an agricultural water right may create a need to develop new storage (to manage the new supply), or conversely, may reduce the need for a storage project designed to tap previously unused streamflows. Similarly, while it may be appropriate in some cases to supplement yields from a new project with an enhanced demand management campaign, it may be viewed as counterproductive to ask a utility to aggressively promote water conservation once new supplies are developed, as the revenues from selling water are needed to cover the capital costs of the new projects.

concluding discussion (in Section 5), how this criterion should be used to make or assess water management decisions is a deceptively complex issue that is only briefly explored herein. Rather, we are content to focus most attention on the presentation of the surprisingly limited cost data, focusing on new projects in Section 2, water transfers in Section 3, and water conservation in Section 4.

(2) New Projects

Cases and Methodology

In our review of the cost of new water supply projects serving the Front Range, we eliminated from consideration projects that were too early in the planning stage or too poorly documented to provide comparable and defensible data. This necessitated that we rely on projects for which detailed public documents—such as Environmental Impact Statements—exist. Additionally, we sought a sub-set of projects that could help us compare water development costs between the northern, central, and southern Front Range. Using these criteria, we selected 28 different water development options~~—described in individual "snapshots" in Appendix A—~~associated with three main efforts, namely:

- **NISP (Northern Integrated Supply Project)** (6 variations).[19] NISP is an effort, coordinated by the Northern Colorado Water Conservancy District, to provide 15 northern Front Range water providers with a firm yield of approximately 40,000 AF of water from the Poudre River. The various options are primarily distinguished by different combinations of three reservoirs—Glade Reservoir, Cactus Hill Reservoir, and Galeton Reservoir (part of the South Platte Water Conservation Project (SPWCP)).

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[19] The full NISP Draft Environmental Impact Statement (DEIS) is available at: https://www.nwo.usace.army.mil/html/od-tl/eis/nisp.deis.apr08.pdf (although this link is frequently disabled). The Executive Summary is at https://www.nwo.usace.army.mil/html/od-tl/eis/nisp.deis.exec-summary.apr08.pdf. Additional information has been compiled by the applicant, the Northern Colorado Water Conservancy District, at http://www.gladereservoir.org/.

- **SMWSA (South Metro Water Supply Authority) Master Plan** (15 variations).[20] This is a largely "conceptual"[21] plan providing a variety of options to provide between 32,100 to 47,800 AF of firm yield to 13 water providers in the southern Denver-metro area. Nine options call for diversions from the South Platte from Greeley, Weldona, or Sterling; while six options call for Arkansas River diversions from either La Junta or Avondale. Options are further distinguished by the number, size, and control of the pipelines that are central to each approach. For purposes of data analysis, the northern (S. Platte) and southern (Arkansas) options are considered as separate projects.

- **SDS (Southern Delivery System)** (7 variations).[22] This effort, led by Colorado Springs Utilities and closely linked to the Bureau of Reclamation's Pueblo Reservoir, features a wide variety of options featuring one or more new reservoirs on Fountain Creek and/or Jimmy Camp Creek, and new pipelines. In the options reviewed, firm yields range from 37,900 to 74,900 AF serving customers spread across Colorado Springs, Pueblo West, Fountain, Security, and Florence.

The primary statistics we compiled for each option are cost (converted to 2010 dollars) and firm yield, which are divided to generate our primary statistic: cost per AF. This approach has several, largely inescapable shortcomings, two of which are particularly salient. First, the methodologies used by the various providers to estimate costs are not identical in terms of what is (or is not) included, financing arrangements, and so on, and are focused on upfront, capital costs. This last item is of particular concern to us, as a distinguishing feature of most new water development proposals in the region is for projects with operating costs that figure to be dramatically higher than past projects, as many involve moving water uphill and often

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[20] South Metro Water Supply Authority (SMWSA). 2007. *Regional Water Master Plan*. Produced for SMWSA by CDM in association with Meurer & Associates; http://www.southmetrowater.org/downloads/SMWSA_MasterPlan.pdf

[21] The report is conceptual in the sense that it is a long term projection of projects that haven't been formally planned yet. SMWSA continues to make adjustments to this plan, thus estimates for firm yields and costs (and other parameters) continues to evolve.

[22] U.S. Bureau of Reclamation. 2008. *Southern Delivery System Final Environmental Impact Statement*. Department of the Interior. http://www.sdseis.com/files/FEIS/FEIS_text1.pdf

involve water requiring extensive treatment. (It is our hope to investigate operating costs in a Phase 2 of this project.) Secondly, project yield can be estimated and reported in a variety of ways; what is most appropriate can be significantly influenced by the intended role of the project.[23] In the interest of standardization, we have chosen to report firm yields—although even this value is subject to different estimates based on an individual providers' design standards, climate assumptions, demand scenarios, system operations, and other factors.

In addition to the 28 "new" projects, we also attempted to compile data for a separate category termed "expansions." This proved impractical, as "expansions" are integrated with existing infrastructure in widely different ways and degrees, thereby discouraging easy classifications and meaningful comparisons. Several projects blur the line between new and expanded projects. For example, in the case of the Rueter-Hess Reservoir, before construction of the initial reservoir was even completed, efforts to enlarge the facility were initiated—ongoing efforts will increase storage capacity more than four-fold! In the case of Aurora's Prairie Waters Project, the project's huge cost-per-AF value—nearly 4 times the average of the other 28 "new projects"—only makes sense when understood that this project is explicitly designed to be expanded over time, both through increased pumping rates and potentially through the addition of existing piping infrastructure. In another case, the Empire Reservoir project, the expansion is probably better characterized as a "repair and expansion," as the structural modifications are largely meant to restore capacity lost over time due to wave erosion. And so on. Ultimately, the only project that seemed an obvious candidate for the proposed "expansion" category was Denver Water's Moffat Collection System Project (MCSP), better known as the Gross Dam and Reservoir enlargement. Data on each of these projects (including 5 MCSP options) is included later in a summary table ~~and in Appendix A~~, but for the reasons identified above, we urge caution in using these numbers, and consider these cases as a supplement to our analysis of the 28 "new projects."

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[23] Different documents/plans emphasize different values. For example, the Southern Delivery System (SDS) Final Environmental Impact Statement (EIS) emphasizes the Simulated Mean Annual Project Delivery (SMAPD), which in some cases is actually lower than firm yield. The SMWSA Master Plan generally avoids using the "firm yield" vernacular, although the explicit goal of the planning exercise is to identify options for meeting firm yield needs. The focus of the MCSP planning documents is on storage capacity estimates more so than firm yields, although estimates of both values are provided.

Results and Discussion

Table 1 provides a summary of firm-yields, total costs (converted to 2010 dollars), and unit costs (costs per AF) for the 28 new project options. Included in this table are sub-totals that lump the projects into 4 sub-categories: (1) NISP (6 options), (2) SMWSA S. Platte (9 options), (3) SMWSA Arkansas (6 options), and (4) SDS (7 options). Unit cost data for these 28 options are plotted in Figure 1. Table 2 includes data for the lowest-cost option in each of the four major sub-categories. Supplemental data regarding expansions, repairs, and other projects are provided in Table 3.

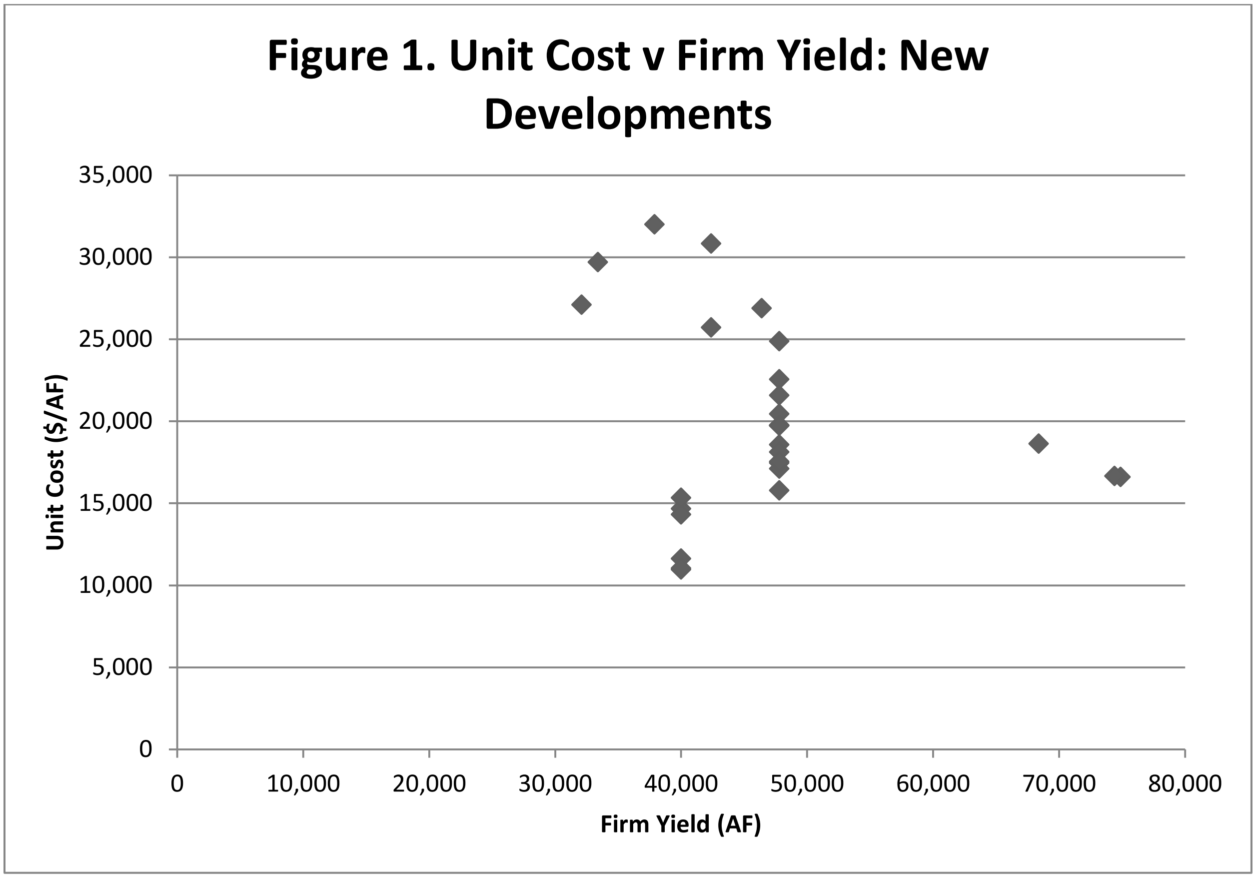

Table 1. Potential Costs of New Water Supply Projects Serving the Front Range

Project: Option	**Firm Yield** (AF/year)	**Total Cost** (2010 dollars)	**Unit Cost** ($/AF)
NISP: Alt 3	40,000	$487,064,400	$12,177
NISP: Alt 4.1a	40,000	$613,960,800	$15,349
NISP: Alt 4.1b	40,000	$599,931,000	$14,998
NISP: Alt 4.2	40,000	$642,229,800	$16,056
NISP: Proposed 1	40,000	$458,900,100	$11,473
NISP: Proposed 2	40,000	$462,145,800	$11,554
NISP Sub-Total	*40,000*	*$544,038,650*	*$13,601*
SMWSA: S. Platte Split- Greeley	47,800	$855,713,100	$17,902
SMWSA: S. Platte Split- Weldona	47,800	$929,003,100	$19,435
SMWSA: S. Platte Split- Sterling	47,800	$988,682,100	$20,684
SMWSA: S. Platte Single- Greeley	47,800	$874,035,600	$18,285
SMWSA: S. Platte Single- Weldona	47,800	$1,023,651,900	$21,415
SMWSA: S. Platte Single- Sterling	47,800	$1,128,351,900	$23,606
SMWSA: S. Platte Shared- Greeley	47,800	$789,856,800	$16,524
SMWSA: S. Platte Shared- Weldona	47,800	$907,330,200	$18,982
SMWSA: S. Platte Shared- Sterling	47,800	$988,368,000	$20,677
SMWSA: S. Platte Sub-Total	*47,800*	*$942,776,967*	*$19,723*
SMWSA: Arkansas Split- Avondale	32,100	$910,785,300	$28,373
SMWSA: Arkansas Split- La Junta	33,400	$1,038,728,700	$31,100
SMWSA: Arkansas Single- Avondale	47,800	$987,321,000	$20,655
SMWSA: Arkansas Single- La Junta	47,800	$1,244,464,200	$26,035
SMWSA: Arkansas Shared- Avondale	47,800	$877,490,700	$18,358
SMWSA: Arkansas Shared- La Junta	47,800	$1,079,457,000	$22,583
SMWSA: Arkansas Sub-Total	*42,783*	*$1,023,041,150*	*$23,912*
SDS: Alt 1	42,400	$1,368,429,000	$32,274
SDS: Alt 2	42,400	$1,141,230,000	$26,916
SDS: Alt 3	74,900	$1,301,211,600	$17,373
SDS: Alt 4	74,400	$1,297,651,800	$17,442
SDS: Alt 5	46,400	$1,306,551,300	$28,158
SDS: Alt 6	68,400	$1,334,087,400	$19,504
SDS: Alt 7	37,900	$1,270,011,000	$33,510
SDS Sub-Total	*55,257*	*$1,288,453,157*	*$23,317*
Average (all 28 projects)	**46,918**	**$960,951,557**	**$20,764**
Weighted Average (total costs/total yields)			**$20,482**

For the 28 project options shown, the average (unit) cost of a new AF of firm yield is $20,764. This figure changes only modestly (to $20,482) by calculating this as a weighted average (total costs/total yields), or by taking the average of the 4 main sub-groupings ($20,138) (not shown). These values are consistent with numbers commonly quoted in the water management community.[24] However, a significant reduction in cost estimates can be achieved by taking the least-cost option in each of the four sub-groupings, as shown in Table 2. Using that approach, average unit costs are reduced to $15,932, or $16,282 if using a weighted average. This approach may be justified on the grounds that, in practice, only one option within each grouping (maximum) is likely to ever be pursued, although there are no guarantees that the least-cost options would be selected. In this report, for purposes of comparison to the other categories of new supply options, the value $16,200 is utilized.

Table 2. Least-Cost New Water Supply Projects

Project: Option	**Firm Yield** (AF/year)	**Total Cost** (2010 dollars)	**Unit Cost** ($/AF)
NISP: Proposed 1	40,000	$458,900,100	$11,473
SMWSA: S. Platte Shared- Greeley	47,800	$789,856,800	$16,524
SMWSA: Arkansas Shared- Avondale	47,800	$877,490,700	$18,358
SDS: Alt 3	74,900	$1,301,211,600	$17,373
Average (4 projects)	**52,625**	**$856,864,800**	**$15,932**
Weighted Average (total costs/total yields)			**$16,282**

Data in Tables 1 and 2 also suggest that new water is more expensive to develop in the southern Front Range than the northern Front Range. Several items support this generalization:

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[24] Other studies and research groups are working on developing cost estimates. Many of these efforts are ongoing, however, data shared to date suggests consistent results. Among the most prominent of the published works is the "*Strategies for Colorado's Water Supply Future*" (2009) report of the Colorado Water Conservation Board. That research suggests that "Identified Programs and Processes" can potentially deliver new water to Front Range users at costs averaging $20,400 per AF.

- SDS water is significantly more expensive than NISP water, whether or not the point of comparison is all the options averaged ($23,317 versus $13,601), or just the lowest cost option within each category ($17,373 versus $11,473).

- SMWSA southern (Arkansas) water is slightly more expensive than SMWSA northern (S. Platte) water, whether or not the point of comparison is all the options averaged ($23,912 versus $19,723), or just the lowest cost option within each category ($18,358 versus $16,524).[25]

As noted earlier, methodological and data issues make it difficult to reach many conclusions about the cost of water acquired through system expansions. Nonetheless, some interesting statistics are provided in Table 3. The unit cost for the MCSP options average $19,334, which is in line with the costs of new developments, although MCSP Alternative 1a (the Proposed Alternative) is quite low at $8,370.[26] At the opposite end of the cost spectrum is Aurora's Prairie Waters Project. Even though the project is coming-in under budget, the unit cost for the initial delivery of 10,000 AF/year of firm-yield capacity is a staggering $68,997. However, it is estimated that this infrastructure—consisting primarily of a pipeline, multiple pumping stations, and a water treatment plant ~~(see Appendix A~~)—will have the capacity to deliver 30,000 AF/year, which drops the unit cost to $22,999, and perhaps more importantly, positions Aurora to play a role in wheeling water to the South Metro region. Firm yield estimates for Empire and Rueter-Hess Reservoirs are not available.

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[25] These price differences are explained by the differences in pipeline length and elevation change. Drawing water from the southern portion of the state requires pipelines between 90 and 130 miles (depending upon the diversion point) and elevation gains that average 3,300ft. Conversely, acquiring water from the northern part of the state requires a pipeline ranging in length from about 40 to 85 miles, and the largest elevation gain required is about 1,100 feet. (*See*: South Metro Water Supply Authority Master Plan, 2007, p. 5-14).

[26] As discussed in Appendix A, MCSP Alternative 1a calls for Gross Dam and Reservoir expansion, but does not include new storage in Leyden Gulch, gravel pits, or the Denver Basin Aquifer, nor does it include the acquisition of agricultural water rights.

Table 3. Expansions, Repairs, and Other Projects				
Project: Options	**Firm Yield** (AF/yr)	**Storage Capacity** (AF/yr)	**Total Cost** (2010 dollars)	**Firm Yield Unit Cost** ($/AF)
Prairie Waters	10,000	--	$689,973,000	$68,997
Empire Reservoir	unknown	2,682	$5,130,300	--
MCSP: Alt 1a	18,000	72,000	$150,663,300	$8,370
MCSP: Alt 1c	18,000	72,000	$316,403,400	$17,578
MCSP: Alt 8a	18,000	57,000	$389,902,800	$21,661
MCSP: Alt 10a	18,000	72,000	$423,511,500	$23,528
MCSP: Alt 13a	18,000	63,625	$459,633,000	$25,535
MCSP Sub-Total	*18,000*	*67,325*	*$348,022,800*	*$19,334*
Rueter-Hess Reservoir	unknown	55,800	$238,087,800	--

(3) Water Transfers

Cases and Methodology

Assessing the cost of water supplies achieved through market transactions may appear relatively straightforward, but in reality, it is exceedingly complex. Four issues are particularly problematic. First, while the state records changes in water rights ownership and requires a "change of use" proceeding in water court for the agricultural-to-urban transfers that are a particular focus of this study, the purchase price is rarely reported. To the contrary, we have found that many buyers and sellers find a strategic advantage in not commenting on prices paid (or received), as this might put them at a competitive disadvantage in future transactions. Second, in addition to the purchase price paid to the seller, the cost of a transferred right includes a variety of "transactions costs"—primarily legal fees and associated engineering studies—that can be significant, but are highly variable and, again, are rarely reported. Third, in addition to transactions costs, many water transfers require new storage, transmission or water treatment infrastructure, or expansions to existing infrastructure; cost information for these elements is also not readily available. And fourth, even when quantified cost data can be compiled, it is difficult to make meaningful comparisons among transferred supplies that vary greatly in terms of seniority (and reliability), location, quality, and related factors. In many respects, quantity is often of much less importance to these other factors in determining the market value of a right. Price comparisons become even more difficult when transfers are pitted against new projects and conserved water. For these other two categories, we have attempted to calculate a price estimate that reflects a “firm” or reliable yield, a quality that aptly describes many of the senior rights transferred, but certainly not all transfers.

After consulting with several water professionals and leading academics, it was concluded that the most complete, trusted, and publicly available dataset of water transfer pricing information does not reside with a public agency, but in a privately published newsletter: the *Water Strategist*.[27] Information gathered by the *Water Strategist* is by no means complete or independently verified, but rather is information voluntarily released to the publication upon request.[28] In this study, we reviewed data from this source from 1990 to 2009, limited to transfers of at least 100 AF or 100 shares in the case of the Colorado-Big Thompson (CBT) project—the most common type of water transfer reported.[29] From this data pool, we removed from consideration all transfers of water for instream or agricultural uses, transferred water that was of low reliability or quality, and a few “special circumstance” outliers that, if included, would significantly (and inappropriately) skew the data. This, admittedly, was an inexact process, but the result is a dataset that includes only transfers of relatively high-reliability agricultural water to municipal buyers.[30] This, we believe, provides the most legitimate point of comparison to water obtained by cities from new projects or conservation. All data was converted to 2010 dollars to further facilitate comparisons, not only between transfers and other means of acquiring new water, but among transfers from different decades.[31]

Results and Discussion

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[27] The *Water Strategist* is a publication of Stratecon, Inc., of Claremont, California; www.waterstrategist.com

[28] The process was described to us in a phone interview with Marta Wiesman, researcher with the *Water Strategist*.

[29] The yield of a CBT share varies over time (in response to hydrologic conditions); the average value is normally estimated at 0.7 AF. In our study, this multiplier is used to convert all CBT purchases to AF. In many cases, the *Water Strategist* lumps multiple transactions into a single purchase.

[30] Technically, a few cases involved transfers between municipalities, but in those situations, the transfer was for water that had recently been acquired from the seller from a farmer.

[31] Throughout this report, adjustments for inflation were based on this Consumer Price Index (CPI) schedule: http://oregonstate.edu/cla/polisci/sites/default/files/faculty-research/sahr/inflation-conversion/pdf/cv2007.pdf.

Based on the methodology and criteria described above, our water transfer dataset contains 121 transactions involving over 31,000 AF of water, a relatively small quantity when compared to many of the proposals reviewed in the preceding “new projects” section. The vast majority of this activity involves CBT shares: 113 transactions totaling 21,644 AF. Results compiled from the entire dataset are provided in Table 4; Table 5 is limited to the CBT transfers. In only one year, 2003, are these values significantly different, with a large non-CBT transfer in that year (between Thornton and Aurora) explaining the difference. Note that the dataset contains data from each of the past ten years (2000-2009), as well as three points in the 1990s (1990, 1994, and 1999). This was done to help illuminate trends and averages. Trends in the last decade are shown visually in Figure 2.

Table 4. Summary of Major Front Range Water Transfers

Year	**Number of Transactions**	**Total Yield** (AF/year)	**Total Price** (2010 dollars)	**Unit Cost** ($/AF)
1990	12	2,857	$8,171,047	$2,860
1994	13	1,957	$6,315,488	$3,227
1999	21	2,699	$22,345,051	$8,278
2000	11	2,146	$45,242,631	$21,080
2001	3	932	$17,289,153	$18,557
2002	8	2,141	$34,803,342	$16,259
2003	12	8,882	$68,069,282	$7,664
2004	8	1,811	$30,409,665	$16,795
2005	6	1,289	$21,556,085	$16,727
2006	7	1,188	$17,249,732	$14,515
2007	5	940	$13,423,692	$14,279
2008	12	4,022	$52,709,074	$13,106
2009	3	378	$4,466,541	$11,816
Total	121	31,241	$342,050,782	$**10,949**

Table 5. Summary of CBT Water Transfers

Year	**Number of Transactions**	**Total Yield** (AF/year)	**Total Price** (2010 dollars)	**Unit Cost** ($/AF)

1990	10	2,549	$7,412,062	$2,908
1994	12	1,757	$5,096,136	$2,900
1999	21	2,699	$22,345,051	$8,278
2000	11	2,146	$45,242,631	$21,080
2001	3	932	$17,289,153	$18,557
2002	7	1,691	$29,978,457	$17,728
2003	11	1,286	$25,928,182	$20,162
2004	7	1,511	$26,731,948	$17,696
2005	6	1,289	$21,556,085	$16,727
2006	6	1,044	$16,740,235	$16,029
2007	5	940	$13,423,692	$14,279
2008	11	3,422	$49,198,900	$14,379
2009	3	378	$4,466,541	$11,816
Total	113	21,644	$285,409,072	**$13,187**

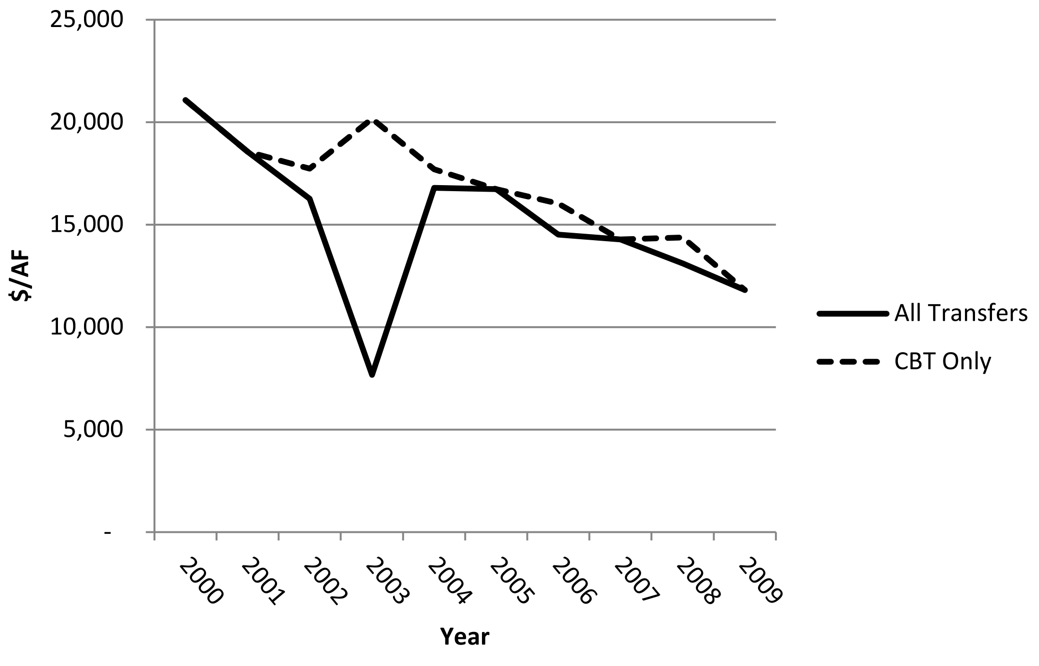

Figure 2. Cost Trends in Water Transfers: 2000 - 2009 (2010$/AF)

The data presented above can be interpreted in several ways. Perhaps the most significant observation is that, while prices jumped sharply to start the new millennium (to over

$21,000/AF in 2000), the rest of the decade featured a steady decline in prices. The only interruption in this decline was a slight jump in CBT prices in 2003, which could presumably be explained as post-drought buying (as 2002 was an extremely dry year), but even this rebound in price was modest and short-lived, and was countered by an unusually inexpensive non-CBT transfer in the same year.[32]

It is also worth noting that, in our dataset, CBT prices tend to be slightly higher than non-CBT prices, but differences tend to be minor (except, as mentioned above, for one transfer in 2003), and reflect too small of a non-CBT sample size to be significant. Furthermore, CBT transfers are generally assumed to feature lower transactions costs, which perhaps offset any price differences that may exist.

For purposes of comparison in this report, we are describing the current cost of an AF acquired through transfer on the Front Range as the weighted average of the 33 transfers from 2005-2009 (totaling 7,817 AF), which is roughly $14,000 (calculation not shown).[33]

(4) Water Conservation

Cases and Methodology

Much like the "new projects" and "transfers" sections of this report, finding data on the cost of conservation is surprisingly difficult, albeit for a very different reason. For conservation efforts, it is often possible to find data about expenditures, but linking those expenditures to quantified water savings is very difficult. The problem lies in the difficulty of comparing water demand to what might have happened in the absence of a conservation program; there is no "control group" *per se*, except for a comparison of demand in past years, which likely featured a

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[32] We expected to see prices increase as a result of drought. However, attempts to correlate prices to the State Water Supply Index (SWSI)—an index specifically designed to measure water availability in Colorado—were not fruitful, as prices generally were higher before, not after, the onset of the most intense drought conditions in 2002. If anything, the relationship between price and water availability has been opposite of what we expected.

[33] The actual calculated value is $13,996.

different set of conditions regarding weather, pricing, economic conditions, and so on.[34] Furthermore, conservation programs are, in most cases, comprised of a set of overlapping actions—perhaps including pricing reforms, public education campaigns, appliance rebates, leak repairs, and so on—which are introduced incrementally. This provides accounting challenges that are very different than assessing the cost of a single new project or water right transfer.

In the following pages, the cost of water conservation on the Front Range is discussed based on data drawn from three primary reports. The first comes from the "Conservation and Efficiency Technical Roundtable" established as part of Phase 2 of the SWSI exercise (2007).[35] The second is an analysis by Denver Water entitled: "*Solutions: Saving Water for the Future*" (2009).[36] The third is a yet unpublished analysis prepared by the Great Western Institute for the Colorado Water Conservation Board.[37] These reports all share the benefit of being recent and deriving from credible sources, and provide a mix of actual and theoretical (projected) savings.[38]

Results and Discussion

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[34] If sufficient data is available, then complex regression equations can be used to assess effectiveness, but this is rarely the case. One notable exception is a study of Aurora by Kenney et al ("*Residential Water Demand Management: Lessons from Aurora, Colorado*" Journal of the American Water Resources Association, 44(1):192-207, February 2008.)

[35] Colorado Water Conservation Board. 2007. *Colorado's Water Supply Future: Statewide Water Supply Initiative Phase 2*, report of the Conservation and Efficiency Technical Roundtable. Department of Natural Resources. http://cwcb.state.co.us/IWMD/SWSITechnicalResources/SWSIPhaseIIReport/SWSIPhaseIIReport.htm

[36] Denver Water. 2009. *Solutions: Saving Water for the Future*, produced by Denver Water, page 3. http://www.denverwater.org/docs/assets/DD81F7B9-BCDF-1B42-DBDA3139A0A3D32D/solutions1.pdf

[37] We are grateful to both the CWCB and GWI for their generosity in sharing this data.

[38] Note that we also considered presenting data compiled from other cities and states based on the idea that some forms of conservation, such as water fixture updates, likely will produce identical savings regardless of location. Ultimately we determined that this supplemental material was not needed, as our "local" data was sufficient and, based on our cursory review, appeared to be generally consistent with findings from other southwestern cities.

The SWSI report examined a variety of indoor and outdoor mechanisms capable of conserving water in the municipal sector, focused primarily on changes to landscaping, water fixtures, and pricing/metering. Several of the options studies are summarized below in Table 6.

Table 6. Potential Long-Term Conservation Savings

Activity	**Potential Savings** (AF/year)	**$/AF** (as reported in 2007 dollars)	**$/AF** (2010 dollars)	***Notes / Assumptions***
Outdoor Initiatives				
Turf Replacement	125,800 to 211,700	$7,000 to $25,000	$7,329 to $26,175	Depending on level of rebates offered
Other Landscape Retrofits	3,100 to 18,400	$2,439 to $10,678	$2,554 to $11,180	
Utility Leak Reduction	52,800 to 86,700	$2,000 to $7,000	$2,094 to $7,329	
Residential Landscape Audits	3,800 to 11,500	$2,000 to $7,000	$2,094 to $7,329	Utility pays $100; customer pays for repairs
Commercial Landscape Audits	1,500 to 5,800	$2,000 to $8,000	$7,329 to $8,376	Utility pays $500; customers pays for repairs
Indoor Initiatives				
Toilet Rebates	55,800	$7,230	$7,570	$150 rebates
Washer Rebates	17,000 to 40,200	$4,000 to $28,000	$4,188 to $29,316	Rebates from $100 to $300
Conservation-Oriented Water Pricing	30,675	$6,000	$6,282	$180 per customer for implementation
Residential Indoor Audits	2,300 to 6,900	$3,600 to $11,000	$3,769 to $11,517	
Commercial Indoor Audits	800 to 3,800	$3,300 to $16,300	$3,455 to $17,066	

Adapted from: *Colorado's Water Supply Future: Statewide Water Supply Initiative Phase 2*, report of the Conservation and Efficiency Technical Roundtable (2007) Table 2-1 (pages 2-6 to 2-8), Colorado Water Conservation Board.
http://cwcb.state.co.us/IWMD/SWSITechnicalResources/SWSIPhaseIIReport/SWSIPhaseIIReport.htm

Producing a weighted average for all conservation measures studies (including some not shown above in Table 6), the report estimates total potential statewide savings by 2030 of 286,900 to 458,600 AF/year at an average cost of $10,600 (in 2007 dollars)—or $11,098 in 2010 dollars. It is worth noting that several options offer the promise of significant yields at very low $/AF costs. For example, summing data for turf replacements (at the lowest rebate level), leak reductions, toilet rebates, washer rebates (at the lowest rebate level), and conservation-oriented pricing regimes suggest it may be possible to achieve roughly 300,000 AF/year of these savings at costs no higher than $7,000 per AF (2010 dollars).

In *Solutions: Saving Water for the Future*, Denver Water provides an accounting of conservation measure effectiveness and cost for efforts that came on-line in 2008[39], focusing on four main program components: (1) residential rebates for low-water use fixtures and appliances; (2) performance contracts with commercial, industrial, and institutional (governmental) customers; (3) irrigation efficiency contracts with homeowners associations, and other irrigation only customers; and (4) indoor fixture retrofits in low-income housing and nonprofit facilities. This data is summarized in Table 7.

Table 7. Denver Water Conservation Savings (2008)

Program Type (and level of activity in 2008)	**Estimated Water Savings** (AF)	**Costs** (as reported in 2009 dollars)	**Costs** (in 2010 dollars)	**$/AF** (2010 dollars)
Washer Rebates (9,561 rebates)	110	$1,436,000	$1,448,451	$13,168
High-Efficiency Toilet Rebates (1,636 rebates)	29	$204,500	$207,472	$7,154
Low-Flow Toilet Rebates (1,241 rebates)	19	$31,050	$31,501	$1,658
Performance Contracts with Commercial, Industrial & Institutional Customers (8 contracts)	91	$273,329	$277,302	$3,047
Irrigation Efficiency Contracts (20 contracts)	185	$162,220	$164,578	$890
Fixture Retrofits for Low-Income Housing & Nonprofit Agencies (1,817 residences)	53	$714,589	$724,975	$13,679
Totals	487	$2,821,688	$2,854,280	**$5,861**

Adapted from: Denver Water. 2009. *Solutions: Saving Water for the Future*, produced by Denver Water, page 3. http://www.denverwater.org/docs/assets/DD81F7B9-BCDF-1B42-DBDA3139A0A3D32D/solutions1.pdf

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[39] It is important to remember that conservation efforts generally involve hundreds of individual "projects" that are constantly coming on-line. Efforts that are implemented in a given year will provide recurring savings, and are joined each year with dozens of new "projects." Thus, savings in any given year may at first seem modest, but quickly become significant when considered over long implementation periods.

As shown above, these efforts in 2008 instituted a recurring savings of 487 AF/year for an upfront cost of $2.85 million (in 2010 dollars), or $5,861 per AF.

Finally, research in progress conducted by the Great Western Institute for the Colorado Water Conservation Board (CWCB) examines Water Conservation Implementation Plans on file with the CWCB. The summary includes a breakdown of each utility's expected program elements, expenditures, and water savings over various planning horizons (usually between 10 and 25 years). Table 8 provides a sub-set of compiled data, focusing on Front Range providers and the $/AF metric, which in this case compares the projected recurring (annual) water savings expected at full program implementation.

A wealth of data is found in Table 8. Overall, the 22 programs reviewed expect, at full implementation, to conserve 63,534 AF of water annually. These savings are attributed to investments of nearly $329 million, which translates to a net (weighted) average cost of $5,173 per AF. While this value is consistent with estimates from the other two studies reviewed, it is worth noting that the $5,173 average hides huge disparities in costs between utilities, ranging from $37,387 in Castle Pines North to $245 in North Table Mountain. If the three highest cost ($/AF) programs (Castle Pine North, Fort Lupton and Aurora) and three lowest cost programs (North Table Mountain, Windsor and Parker) are removed from the analysis, the spread between high and low-cost programs shrinks dramatically, ranging from $8,406 to $696. Removing these outliers only reduces the overall level of water conserved to 56,858 AF (a less than 11 percent reduction from the full sample), yet reduces the $/AF value to $4,572.

Table 8. Summary of Data from Water Conservation Implementation Plans			
Location / Utility	**Total Cost** (over planning	**Total Water Savings** (in AF, over planning	**Average Cost** ($/AF)

	horizon)	horizon)	
Arapahoe County Water and Wastewater Authority	$517,330	346	$1,495
Aurora, City of	$55,750,000	2,533	$22,009
Boulder, City of	$11,325,000	4,750	$2,384
Brighton, City of	$3,879,892	1,000	$3,880
Castle Pines North	$7,477,335	200	$37,387
Castle Rock, Town of	$17,300,000	3,300	$5,242
Centennial	$1,768,750	933	$1,897
Colorado Springs	$43,918,296	8,508	$5,162
Denver Water	$151,374,000	29,400	$5,149
East Larimer County	$3,069,337	572	$5,366
Evans	$1,298,777	706	$1,840
Fort Collins Loveland Water District	$805,550	1,158	$696
Firestone, Town of	$1,020,230	140	$7,287
Greeley, City of	$15,000,000	3,000	$5,000
Left Hand Water District	$677,640	644	$1,052
Longmont, City of	$3,320,379	1,600	$2,075
Fort Lupton, City of	$3,646,920	156	$23,378
Northglenn, City of	$4,018,015	478	$8,406
North Table Mountain	$173,810	710	$245
North Weld County	$655,233	323	$2,029
Parker Water and Sanitation District	$1,502,000	2,691	$558
Windsor, Town of	$150,313	386	$389
Total	**$328,648,807**	**63,534**	**$5,173**

As with the “new projects” and “water transfers” sections, it is difficult to select one value as the representative cost of conserved water. As discussed above, the SWSI average of $11,098 (per AF) does not discriminate between the high-cost and low-cost options; focusing on the low cost options—as would happen in practice—suggests an upper limit no higher than $7,000. The two other studies reflect this real-world selection, as the Denver Water study reports efforts already implemented (costing $5,861), while the GWI/CWCB data is for programs already in place (but not yet fully implemented). The cost of those programs is estimated at $5,173 per AF, or $4,572 once the high and low outliers are removed. Given these considerations, we have chosen to use the value of $5,200 AF as a fair estimate of the average cost of conservation on the Front Range.

(5) Summary and Conclusions

Three major themes emerge from the compilation and comparison of cost data. First, cost data is extremely difficult to find. Given the magnitude of the dollars involved, and the fact that the money spent and the obligations incurred belong to the public, we found this to be both odd and troubling. Second, the values we have compiled are deficient in many ways, as they are not produced using standardized assumptions, and in most cases are confined to upfront capital expenditures. By using the cost per AF metric across all categories, we standardized the data to the extent possible; nonetheless, the numbers presented should be considered as generalizations. And third, despite our concerns about the availability and quality of information, the data is sufficient to indicate that water obtained via conservation is, by far, the cheapest option. To review, our estimates of representative costs (in $/AF) are as follows: new projects, $16,200; water transfers, $14,000; and conservation, $5,200.

Selecting among possible water management options is often among the most important decisions made by city government. Determining which options are “best” is a complex matter, as it entails an assessment of highly case-specific opportunities, constraints, trade-offs, and risks, all overlain by value choices. Cost is only one consideration. Still, one cannot help but be struck that the approaches pursued by most cities—as measured by rhetoric, effort, action, and expenditures—is the opposite of what is suggested by the cost per AF metric.

Unlike many utilities and other areas of public policy-making where regulatory bodies issue and enforce decision-making criteria, many decisions in the M&I water sector are often as simple as a city council asking for, and then accepting, a recommendation from the water utility. While there is an obvious logic to this approach, a wide variety of water resource scholars, environmentalists, and ratepayer advocates have suggested that those recommendations often are unduly shaped by disciplinary norms and utilitarian values, disproportionately favoring engineering and supply-based options over “softer path” options based primarily on modifying water use behavior. Following this logic, the focus on new projects is often attributed to “cultural” factors such as the predominance of water supply engineers in leadership roles in water agencies, the political benefits that accompany new public works projects, the social pressure to avoid dewatering agricultural lands, and so on.

Another stream of thought points to the different roles that accounting conventions and economic theory play, or could play, in shaping water decisions. Unlike a private business whose decisions are evaluated based on its accrual of profits or losses, or similarly, its ability to maximize benefits relative to costs, public water utilities are merely charged with meeting the annual accounting standard of ensuring that revenues cover expenditures—something that is easy for the utility to achieve by controlling water prices charged to customers. This subordinates the role played by cost-effectiveness measures in water utility decision-making[40] , and thus negates any cost per AF advantage that conservation might have over new project or transfer options. It also gives the water agency an inherent disincentive to conserve supplies once developed.

Many water managers counter that the subordination of conservation strategies is not a function of ideology or accounting practices, but is a practical response to three concerns. The first is “demand hardening,” which occurs when water saved through conservation is used to support new growth.[41] As more and more people become dependent on a fixed supply of water, then the ability to deal with dry periods decreases, as options for emergency conservation have already been exhausted by conservation programs that have removed the

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[40] Perhaps the best way to appreciate the conflict between accounting conventions and economic theory is to look at water pricing. Economic theory dictates that the price charged for water should be based on its marginal cost—i.e., the cost required to produce one more unit. In this way, customers are given proper signals about the costs that they will incur should their demand increase further. Since new projects are inevitably more expensive (often dramatically so) than old projects, marginal cost pricing provides a strong conservation message. In contrast, utilities generally prefer average-cost pricing, in which the cost of all system elements (both old and new) are averaged together, thereby hiding the escalating costs of new water, and encouraging a growth in demand that generates calls for new projects. Once built, the pressure is then on the utility to promote further growth in demand, as the only way to meet the cost-based accounting standard is to promote a project’s full utilization. Again, this is only possible by averaging the costs of new development in with existing system elements, thereby re-violating economic theory and initiating another rushed outgrowth of supply.

[41] Of course, conservation does not necessarily have to create demand hardening. Rather than using conserved water to support new growth, it can be used to increase storage, protect (and enhance) firm yields, and support instream flows and other non-consumptive uses. Ultimately, the value of conservation is directly tied to the intended use of the saved water, and that is often a decision over which the water utility has very little control.

slack and inefficiencies from the system. The second factor is competition for remaining water. There is only a finite amount of “unused” water left for development in new projects, and the cities that act first will secure the majority of that water. Savings achieved through conservation, in contrast, is water that the utility has “in their back pocket,” available for development at any time without fear of competition from other utilities. A third (and closely related) issue is the time frame of implementation. The fact that conservation programs can be implemented with very little lead time while new supply projects can take decades to conceive and build is seen by many as an argument for “getting started now” with new projects. Conservation will always be available, but the window for building new projects is closing as others compete for that same water and as the costs of development increase.

Ultimately, pursuing more economically defensible water management may require reconsidering several procedural and substantive elements of water resources decision-making, all supported by a more explicit commitment to compile and consider cost data. This last item has been the focus and contribution of this report, but even in this modest role, we must conclude again acknowledging that our data is limited and incomplete. Of particular concern is the omission of any data other than upfront, capital costs. Environmental externalities, social costs, and operational (e.g., energy) costs are all undoubtedly significant, and if included, would only further strengthen the observation that the typical utility preference scale of new supply options generally runs opposite to what a full accounting of costs would suggest.