RECLAMATION

Managing Water in the West

Los Angeles Basin Stormwater Conservation Study

Task 6 – Trade-Off Analysis & Opportunities-DRAFT

U.S Department of the Interior
Bureau of Reclamation
Technical Service Center
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Cover Photo: Morris Dam on the San Gabriel River, Los Angeles County, California.

Los Angeles Basin Stormwater Conservation Study

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December 2015

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Executive Summary

The Los Angeles Basin Stormwater Conservation Study (LA Basin Study) is a collaborative partnership between the Los Angeles County Flood Control District (LACFCD) and the U.S. Department of the Interior, Bureau of Reclamation (Reclamation). The purpose of the LA Basin Study is to investigate long-range water conservation and flood risk management impacts caused by projected changes in climate and population in the Los Angeles region. The LA Basin Study highlights opportunities for potential modifications and changes to the existing regional stormwater capture system, as well as for the development of new facilities and practices, which could help to resolve future water supply and flood risk management issues. The stormwater capture project concepts and alternatives developed in the *Task 5 – Infrastructure & Operations Concepts* Report informed the trade-off analysis and opportunities highlighted in this report.

The primary purpose of *Task 6 – Trade-Off Analysis & Opportunities*, is to evaluate the quantifiable benefits and costs of the stormwater concepts identified in Task 5 and to provide an analysis of the trade-offs between concepts. In most cases, various project concepts would generate benefits for some impact categories but not others, and would also impose various types of costs. The trade-off analysis provides a methodology for comparing different types of benefits and costs. These trade-offs include economic, financial, environmental, and social effects. Economic effects include: the benefits associated with different types of goods and services supported by the concepts, the costs of the different concepts, the impacts of the different concepts on the regional economy through changes in the amount and type of spending, and the cost effectiveness of different project concepts. Financial effects reflect the impacts of paying for a project, such as paying off capital debt and covering operation and maintenance expenses. Environmental effects reflect the type and quality of environmental and natural resources that would be potentially influenced by a concept. They include items such as water quality, energy consumption, impacts on habitat, and ecosystem function. Social effects reflect how the concepts may alter the social characteristics of a community or region. Examples of social effects include education, environmental justice, and quality of life.

Benefits are quantified for additional stormwater conserved or stored in acre-feet per year, and recreation in terms of miles of new trails, increased habitat acreage, and additional acquisition of right-of-way acreage. Stormwater conservation benefits are valued as improved water supply reliability, recreation is valued as a type of general recreation activity similar to outdoor activities at a local park, and habitat acreage is evaluated as a type of ecosystem improvement. In the case of the Regional Impact Programs Concept, right-of-way acreage also produces some ecosystem benefits. Quantified benefits and costs are summarized in Table ES-1.

All benefits and costs are present value over a 50-year planning period using the current Fiscal Year 2016 federal water project planning rate of 3.125%.

In addition to quantitative benefits, the trade-off analysis also utilizes qualitative information from the Task 5 Report to estimate concept benefits. These qualitative benefits included items such as flood risk, water quality, aesthetics, heat island mitigation, and climate resiliency. Additional information is obtained from the California Communities Environmental Health Screening Tool to evaluate additional social, environmental, and environmental justice issues.

The various categories of effects included in the trade-off analysis would not be expected to be of equal importance to local stakeholders or to the general public. To account for this, a survey of the Stakeholder Technical Advisory Committee (STAC) members was conducted to determine the relative importance of each of the quantitative and qualitative effects. Each impact measure was rated on a 1 to 10 scale, where 1 is least important and 10 is most important. The survey results were then used as the basis for weighting each effect category to determine a final trade-off score that represents a combination of all impact categories. The weights used in the trade-off analysis are summarized in Table ES-2. The highest possible score in Table ES-2 is a 10.0, which would reflect the impact measure that has the highest total number of points across all STAC survey respondents.

The trade-off analysis incorporated the information for quantitative and qualitative impacts for each concept group and the importance weights to calculate a final score for each project group. All scores prior to weighting are measured relative to the highest scoring concept plan. This approach allows all quantitative and qualitative effects to be expressed as unit-less values that are comparable across the different effects. Higher scores indicate higher combined benefits. The results of the trade-off analysis are shown in Table ES-3.

Theoretically, the maximum average score for a project is 100 and the maximum sum of scores is 1,500. However, this would only occur for a concept that is the best at every possible category, and this could only occur if there are no trade-offs for this particular concept. A perfect concept does not exist, so the scores shown in Table ES-3 need to be compared on a relative basis.

The economic analysis of quantified benefits can be used to evaluate the magnitude of potential benefits of each project group, recognizing that many additional benefits may exist that are not accounted for in a traditional benefit analysis.

The economic analysis indicates that the LACFCD Dams project group is the only concept that generates quantified benefits in excess of project costs. The next tier of project groups with benefits that are in the 10% to 20% range of costs are the group of Local Solutions and the Regional Stormwater Capture project groups. Although these concepts do not generate quantified benefits in excess of costs,

they do generate benefits that are greater than the other concept plans, again with the exception of the LACFCD Dams project group.

It should be noted, however, that Local Solutions and Regional Solutions generate moderate to high qualitative benefits, while the Storage Solutions generate low qualitative benefits. With this in mind, if the qualitative benefits are targeted as the primary focus, then using only the quantified economic benefits (cost specifically) as the priority measure would lead to an incorrect conclusion. In other words, if multi-benefit is the most important goal for considering a set of projects, but then at the end of the analysis only the cost is used as the final justification for the set of projects, then this side-steps the goal of the multi-benefit and undoes the economic trade-off analysis process. This is an important distinction between a financial analysis and an economic analysis.

The weights used as a basis for computing project group scores indicate stormwater conservation and water quality are at a level of importance that is substantially higher than other categories. The second tier of importance includes climate adaptation, flood risk mitigation, and pollutant & environmental impact. These results indicate that project groups targeting these five categories of benefit will provide the greatest level of overall benefit to the region and to the general public. However, the other impact categories are still important and should not be ignored. It is also important to note that of the top five categories of importance, benefits were quantified in monetary terms for only the stormwater conservation category. This result provides support for the use of a trade-off analysis to aid in understanding the full benefits of the concept plans.

The trade-off analysis indicates that the Local Solutions, Regional Impact Programs, and Green Infrastructure Programs produce combinations of benefits that have a higher value than the other concepts. However, the results of the trade-off analysis can be evaluated based on individual impact categories to compare impacts that are of greatest importance to an individual, agency, or group.

The final results of the economic and trade-off analysis should not be used in isolation to evaluate and compare the project groups, but should instead be used as a baseline evaluation that can be adjusted to represent particular resources and impacts of interest.

Table ES-1: Best Estimate of Benefits and Costs over the 50-year Period of Analysis Associated with LA Basin Study Concepts

Concept	Present Value of the Best or Mid-point Estimate of Quantified Benefits (Million $'s)	Present Value of Capital, Land, and Operation and Maintenance Costs (Million $'s)
Local Solutions		
Local Stormwater Capture	748	7,153
Low Impact Development	519	21,055
Complete Streets	172	12,253
Regional Solutions		
Regional Stormwater Capture	252	1,320
Stormwater Conveyance Systems	54	10,346
Alternative Capture	34	226
Storage Solutions		
LACFCD Dams	832	667
USACE Dams	40	N/A
Debris Basins	3	74
Management Solutions		
Stormwater Policies	946	227,362
Green Infrastructure Programs	677	26,681
Regional Impact Programs	896	116,661

Table ES-2: Weights used for Impact Categories

Impact Measure	Final Weights Used in Trade-Off Analysis
Stormwater Conservation	10.0
Water Quality Impact	8.86
Climate Adaptation	7.99
Flood Risk Mitigation	7.98
Pollutant & Environmental Impact	7.66
Operations & Maintenance Cost	7.15
Ecosystem Function	6.93
Environmental Justice Impacts	6.82
Energy Impact	6.74
Capital Cost	6.67
Connectivity	6.52
Habitat	6.31
Environmental Compliance and Regulatory Permitting	5.90
Recreation	5.46
Financial Impact	5.20

Table ES-3: Weighted Final Scores of Concepts

Concept	Final Weighted Scores for Concepts	
	Average Score (Max of 100)	Sum of Scores (Max of 1500)
Local Solutions		
Local Stormwater Capture	44	660
Low impact development	37	558
Complete streets	36	543
Regional Solutions		
Regional Stormwater Capture	36	537
Stormwater Conveyance Systems	31	464
Alternative Capture	36	534
Storage Solutions		
LACFCD Dams	41	613
USACE Dams	22	326
Debris Basins	32	475
Management Solutions		
Stormwater Policies	34	504
Green Infrastructure Programs	38	568
Regional Impact Programs	41	607

Introduction

The Los Angeles Basin Stormwater Conservation Study (LA Basin Study) is a study of the long-term water conservation and flood risk impacts from projected climate conditions and population changes in the Los Angeles Basin. The LA Basin Study provides information regarding potential modifications and changes to the existing regional stormwater capture system and development of new facilities and practices, which could help to resolve future water supply and flood risk management issues due to climate change. The LA Basin Study provides potential changes that would be effective in resolving these issues. Task 6 provides a comparison of the various effects associated with each concept identified in the *Task 5 – Infrastructure & Operations Concepts* Report. This analysis includes economic, financial, environmental, and social measures of the impacts from a concept. Some effects are quantified and monetized, some are quantified but cannot be monetized, and some effects can only be evaluated qualitatively. Multi-criteria evaluation techniques are used to compare the wide variety of effects associated with the concepts in Task 5.

Study Background and Study Area

The Los Angeles County Flood Control District (LACFCD) has been considering the possibility of large-scale enhancement of the LACFCD's water conservation capabilities through the study of long-term projected needs and projected climate conditions. Informal discussions occurred between LACFCD and several major water agencies on the same subject. As a result, this interest was the driving force for creating a partnership between the LACFCD and U.S. Department of the Interior, Bureau of Reclamation (Reclamation) under the Basin Studies Program (Reclamation 2009). The LA Basin Study provides an opportunity for multiple water management agencies to participate in a collaborative process to plan for future local water supply conditions and examine potential enhancement of existing facilities or the development of new facilities that will benefit water agencies and local communities.

Previous analyses completed as part of the LA Basin Study that have a direct impact on the economic and trade-off analysis have included *Task 2 – Water Supply & Water Demand Projections*, which developed estimates of future water demand and water resources available to meet potential future demand, and *Task 5 – Infrastructure & Operations Concepts* Report, which developed structural and nonstructural concepts to manage stormwater under future conditions. The Task 2 analysis is important to the economic and trade-off analysis because the difference between water supply and demand is the basis for economic value and need. The Task 5 analysis provides details of the resources affected by the concepts, including

but not limited to the range of potential stormwater water supply and storage, open space, recreational opportunities, and energy consumption.

Task 6 analysis utilizes existing information from Task 5 and other related studies to value and evaluate the effects of various concept impacts. Highlighted opportunities from the LA Basin Study concept development and trade-off analyses will provide guidance for further local water supply development planning, financing strategy, and policy adoption for LACFCD and other LA Basin Study partners.

The Los Angeles River, San Gabriel River, South Santa Monica Bay, North Santa Monica Bay, Ballona Creek, Malibu Creek, and Dominguez Channel/Los Angeles Harbor watersheds are included in the LA Basin Study. The LA Basin Study area includes several large groundwater basins and existing dams and reservoirs. According to the Task 2 analysis, the Study Area includes more than 9 million people, and covers approximately 1,900 square miles. Los Angeles County accounts for the largest amount of water demand of any urbanized county in California.

Economic and Trade-Off Analysis

The primary purpose of Task 6 is to evaluate the quantifiable benefits and costs of the stormwater capture concepts identified in Task 5 and to provide an analysis of the trade-offs between each concept. In most cases various concepts will generate benefits for some impact categories but not others, and the trade-off analysis will provide a methodology for comparing different types of benefits and costs. These trade-offs include economic, financial, environmental, and social effects. Economic effects include the benefits associated with different types of goods and services supported by the management concepts, the costs of the different concepts, the impacts of the different concepts on the regional economy through changes in the amount and type of spending, and the cost effectiveness of different concepts. Examples of financial effects include the impacts on water utility revenues and expenditures, impacts on utility bills, fiscal impacts on state and local governments, and the ability of water users to pay for different concepts. Environmental effects reflect the type and quality of environmental and natural resources that would be potentially influenced by a concept. Environmental effects would include items such as water quality, energy consumption, impacts on habitat, and ecosystem function. Social effects reflect the social characteristics of a community or region. Examples of social effects include education, environmental justice, and quality of life.

A basin study is typically an appraisal-level analysis, relying on existing data and information to evaluate impacts and assess trade-offs. As a result, some areas of measurement and evaluation in the trade-off analysis will be fairly general and

uncertainties will exist. These uncertainties are identified as part of the trade-off analysis.

Steps in Completing a Trade-Off Analysis

The first step in completing an economic and trade-off analysis is to obtain measures of outputs associated with each stormwater capture concept that can then be compared across concepts. Ideally these outputs will be quantified in units that represent relative values for different categories of benefits. This step is highly dependent on outputs identified and computed as part of Task 5.

The second step is to place values on the identified outputs that are readily quantifiable. This step is the economic benefit and regional impact portion of the analysis. Economic benefits represent an improvement in social welfare as measured by the net economic value of goods and services provided as a result of a project or action. Economic benefits can be compared to project costs to evaluate economic feasibility. If benefits exceed costs, then a project is considered economically feasible and justified. Regional impact analysis is used to evaluate the economic effects of a project on the local area. Regional impacts include effects on income, employment, and the value of regional output associated with the various alternatives.

The third step is to complete the trade-off analysis based on changes in resources derived from Task 5, the impact of changes in resources on human activities, and the value of those changes in activities when they can be measured.

Benefits Identified in Task 5 – Infrastructure & Operations Concepts

The Task 5 Report quantified some concept impacts and provided a list of potential unquantified impacts. These impacts are presented in Table ES-1 and Table 41 of the Task 5 Report and are presented below in Tables 1 and 2. It should be noted that some recreational qualitative impacts in addition to miles of recreation trails were identified in Table 41 of the Task 5 Report, but the emphasis is on miles of trails in this analysis. These impacts identified in the Task 5 Report are an important part of the assessment of potential concept benefits.

Table 1: Impacts Quantified in Task 5 – Infrastructure & Operations Concepts

Project Group	Stormwater Conserved/Storage Capacity		Recreation (miles of trail)	Habitat (acres)	Right of Way Acquired (acres)
	Low	High			
Local Solutions					
Local Stormwater Capture	17,900	29,300	204	266	2,655
Low Impact Development	81,400	131,600	0	0	0
Complete Streets	27,300	43,300	0	0	0
Regional Solutions					
Regional Stormwater Capture	26,100	59,900	12	42	682
Stormwater Conveyance Systems	8,000	10,000	3	8	31
Alternative Capture	3,800	6,900	2	2	34
Storage Solutions					
LACFCD Dams	57,400	264,100	0	0	0
USACE Dams	3,800	11,800	0	0	0
Debris Basins	90	230	1	0	0
Management Solutions					
Stormwater Policies	155,300	235,000	0	0	0
Green Infrastructure Programs	106,400	171,800	0	0	0
Regional Impact Programs	21,800	36,900	527	5,200	7,600

Table 2: Unquantified Benefits Identified in Task 5 – Infrastructure & Operations Concepts

Project Group	Flood Risk	Water Quality	Aesthetics	Heat Island Mitigation	Climate Resiliency
Local Solutions					
Local Stormwater Capture	High	High	High	High	High
Low Impact Development	Moderate	High	High	High	High
Complete Streets	Moderate	High	Moderate	Moderate	High
Regional Solutions					
Regional Stormwater Capture	Low/No	High	Moderate	High	High
Stormwater Conveyance Systems	Moderate	Moderate	High	High	High
Alternative Capture	Moderate	High	Moderate	High	High
Storage Solutions					
LACFCD Dams	Moderate	Low/No	Moderate	Low/No	High
USACE Dams	Moderate	Low/No	Moderate	Moderate	High
Debris Basins	Moderate	Moderate	Low/No	Low/No	Moderate
Management Solutions					
Stormwater Policies	Low/No	High	Moderate	Moderate	High
Green Infrastructure Programs	Moderate	High	High	High	High
Regional Impact Programs	Moderate	High	High	High	High

Value of Conserved and Stored Water

Stormwater conservation and storage is a primary benefit associated with each of the concepts. Stormwater conserved by the various concepts represent potential supplemental water supplies to the region which could be used for residential, commercial, industrial, environmental, agricultural, and other uses. The value of water supplies can vary greatly depending on the location and end use of the water. A wholesale value for residential water is used to value supplemental water supplies for this analysis. More specifically, a value associated with water supply reliability is applied to represent the value a raw water supply that would help bridge the potential difference in future water supply and demand identified in the *Task 2 – Water Supply & Water Demand Projections* Report (Task 2 Report) during drought periods. This condition would best represent the likely benefit associated with the concepts. In addition, municipal and industrial water supplies are typically among the highest valued uses and would, therefore, ultimately benefit from supplemental water supplies in the event of a water supply shortage.

Benefits of Improved Water Supply Reliability

Two basic pieces of information are required in order to estimate the benefits associated with increased or improved water supplies: the quantity and quality of the water supply provided, and the value of the good or service supported by the water supply. The quantity of water provided by each project concept is provided by the Task 5 Report. The economic benefits associated with increased water supplies are represented by the willingness of water users to pay for additional units of water provided by a project, program, or policy (U.S. Water Resources Council, 1983). Willingness to pay can be defined as the dollar amount that an individual is willing to give up or pay to acquire a good or service. Four basic approaches can be used to measure willingness to pay.

1. Stated preference approach – The use of survey data to directly estimate benefits based on the stated willingness to pay of water users for an improved water supply.
2. Revealed preference approach – Using actual observed market behavior to derive the value of a good or service. Markets reveal the preferences of an individual through the prices paid for and quantities purchased of a good or service. Market price and quantity combinations can be used to estimate willingness to pay functions from which benefits can be estimated.
3. Benefits transfer approach – The use of results from previously completed studies to estimate benefits for a plan or project under consideration. The accuracy of benefits-transfer-based estimates depends on the similarity between the site where the original detailed analysis was completed and the site of interest where the transferred benefits are applied. Similarity can be defined in terms of economic conditions, population characteristics, resources within an area, or other characteristics. Application of the benefit

transfer method assumes that the relationship between a resource improvement and economic value in one area can be estimated and applied to another geographic area or resource.

4. Cost-based approaches – Using the resource cost of a water supply alternative that would be implemented in the absence of the project under consideration as an estimate of benefits. This approach will accurately represent willingness to pay only under specific, restrictive conditions. Using a cost-based approach to estimate benefits will always result in an economically justifiable project because the lowest cost alternative will have positive benefits regardless of actual willingness to pay.

The above approaches each have advantages and disadvantages. The stated preference approach has the advantage of reflecting values for the specific change in resources resulting from a concept. However, the values estimated using stated preference are based on hypothetical market values. The accuracy of these hypothetical values can be improved through careful survey design, but some inherent biases may still exist. The revealed preference approach has the advantage of being based on actual behavior, but is limited by the availability of market data that reflects competitive market forces. The benefits transfer approach is much less time consuming and methodologically easier to implement than the first two approaches because it does not require the collection of primary data and econometric modeling to be completed. However, the benefits transfer approach is dependent on the availability of existing studies that are applicable to the study area and the resource under consideration. As a result, the benefit estimates may not be as accurate as those derived via the stated and revealed preference approaches. Finally, the cost of the most likely alternative approach has the advantage of being less data intensive because it does not require estimation of demand relationships from which willingness to pay is derived. However, this is also the primary disadvantage of the approach. Cost-based approaches do not measure willingness to pay, but simply measure the cost of other alternatives that would achieve a goal. The cost of an alternative project may be less or greater than actual willingness to pay.

Given resource and time constraints as well as limited input data available, the benefits transfer approach is used in this analysis. There are four basic steps in the application of benefits transfer:

1. Obtain estimates of water supply reliability benefits from previously completed studies. The water reliability studies found in the literature review all estimated benefits at the retail household level.

2. Convert the retail level reliability benefits to the wholesale level appropriate for this analysis. In addition, the studies found in the literature search all estimated benefits on a per household basis.

3. Convert the stormwater conserved or stored estimates in acre-feet into a potential number of households served. The number of potential households

served can then be applied to the estimated benefits per household found in the literature.

4. Lastly, multiply the estimated number of potential households served by each concept by the estimated wholesale water supply reliability benefit per household to derive an annual water conservation/storage benefit estimate.

The assumption in the use of benefit transfer is that the resource characteristics at the site from which benefit estimates are estimated (the study site) are similar enough to the area for which benefit estimates are needed (the analysis site) that the estimated benefits are representative of values. It should be noted that the benefits transfer approach is considered an acceptable approach for measuring willingness to pay at an appraisal level, where the purpose of the analysis is to present information on the expected magnitude of benefits and to assist in screening alternatives for further analysis. However, it is generally recognized that benefit transfer is not as accurate of a method for estimating benefits as completing an original research analysis.

It should be noted that another type of analysis that is frequently used to compare alternatives is cost effectiveness. The basic approach used to evaluate cost effectiveness is to simply compare the unit cost of different methods that can be used to generate a desired good or level of service. For example, if a water supply can be augmented by either obtaining water from an available surface water source or by recycling and treatment, then cost effectiveness analysis would compare the cost of providing an acre-foot of water (assuming water quality is the same) using the two approaches, and the one with the lowest cost would be considered cost effective. The primary advantage of this approach is that only two pieces of information are needed, the cost of an option and the quantity of good or service provided. The disadvantage is that it is not known if the most cost effective option actually generates benefits in excess of costs.

Previously Completed Water Reliability Studies

Most of the previously completed water supply reliability studies have relied on survey data to estimate benefits. Similarly, questionnaires are used to ask water users how they would react to different magnitudes of shortages and various event probabilities and how much they would be willing to pay to avoid those shortages. In some studies the question was also posed in terms of the willingness to accept payment for a reduction in reliability either in terms of increased shortage duration or an increased probability of a shortage. The use of surveys and hypothetical conditions to derive benefit estimates is called the stated preference approach and is an accepted approach for measuring resource values. However, it should be noted that some economists believe that the hypothetical nature of the stated preference approach creates the potential for biased results. Five previously completed water reliability benefit studies are discussed below.

Barakat and Chamberlin Study

A study prepared by Barakat and Chamberlin (1994) estimated the mean monthly willingness to pay (WTP) of residential water customers in southern California to avoid water supply shortages. Mean monthly WTP was estimated to range from $11.13 to $16.93 per household per month in 1993 dollars, or $16.52 to $25.13 in 2014 dollars using the Bureau of Economic Analysis Implicit Price Deflators for personal consumption expenditures to adjust prices. This translates into a range of $198 to $302 annually per household. The lowest value was for a 10% reduction once every 10 years and the highest was for a 50% reduction once every 20 years. There were several iterations between the range of values, with different reductions in service (10% increments from 10% to 50%) and frequency of occurrence (from 1 in 3 years to 1 in 30 years).

There are several interesting observations that can be made about the estimates in the Barakat and Chamberlin study. The difference in WTP in Southern California to avoid a 10% reduction in service every 3 years versus a 10% reduction every 10 years is only $0.51 per month or $6.12 per year in 1993 dollars or $0.76 per month and $9.08 per year in 2014 dollars, a difference of only 4.6%. Similarly, the difference between WTP to avoid a 40% reduction in service every 10 years versus a 40% reduction every 30 years is only $19.68 annually in 1993 dollars and $29.21 in 2014 dollars. This seems to indicate that people may not properly account for the impact of shortages in the future (perhaps this is an indication of heavily discounted future effects). However, the discounting argument probably does not explain the small difference in willingness to pay to avoid a 10% shortage every 3 years compared to every 10 years. One possible explanation is that while an event occurring every 3 years is quite frequent, perhaps a 10% shortage is not seen as an undue burden that is worth paying something to avoid.

It is also interesting to note that the confidence interval for the Southern California Model is estimated to be +/- $0.51, which means that there is no statistical difference between a 10% shortage every 3 years or a 10% shortage every 10 years. This may indicate that the survey respondents are not correctly interpreting the service being presented in the questionnaires. As a result, the survey results may not correctly value water supply reliability.

The results of the Barakat and Chamberlin study indicate the incremental change in the willingness to pay to avoid a water shortage decreases as the shortage (as a percentage of total demand) increases. For example, the WTP to avoid a 40% shortage every 10 years is only 43.9% higher than the WTP to avoid a 10% shortage every 10 years even though the frequency of shortage is 4 times (400%) higher. Economic theory would generally suggest that the value of a good that is in short supply would tend to increase as the shortage worsens and the willingness to pay to avoid a loss would also tend to increase. The law of diminishing returns and the concept of diminishing marginal utility would explain why the value of water as an input into production or utility tends to increase as less is available. As a result, individuals would be expected to be willing to pay more to avoid a 1% reduction in a shortage when the shortage is very large than to avoid a 1% reduction in a

shortage when the shortage is small. However, the Barakat and Chamberlin study showed the opposite result.

The above discussion of the Barakat and Chamberlin study indicates that there may be some inconsistency in the survey respondent estimates of WTP to avoid water supply shortages and therefore there may be some error in the estimates themselves. The inconsistency may be due to the respondents misunderstanding the survey questions, specifically the meaning of the shortage percentages and the probability of a shortage occurring. For example, the respondents may be able to understand the meaning of a 1 in 3 year occurrence because 3 years is a relatively short timeframe, but the difference between a 1 in 20 year occurrence and a 1 in 30 year occurrence may not be distinguishable if respondents perceive 20 and 30 years similarly as far into the future. However, the estimated range of WTP to avoid reliability problems provides information on the perceived benefits from avoiding a water shortage. Therefore, the focus of the estimated values from Barakat and Chamberlin should not be on the specific values for each shortage percentage and frequency of occurrence, but the range of values associated with some type of shortage.

Orange County Study

A 2003 study prepared for the Municipal Water District of Orange County (Orange County Business Council, 2003) focused on one region using information from the 1994 Barakat & Chamberlin study as well as providing estimates of business impacts, employment impacts, and landscape impacts based on information from several independent studies.

The Orange County study indicated that over the 1993 to 2003 period there had been a rapid increase of the service sector, and projections at the time indicated continued growth in that sector. The service sector had grown by 56% from 1999 to 2006, manufacturing had grown 18%, and retail trade had grown 11%. Areas of growth from 1988 to 2001 were identified as textiles (+157.9%), aircraft and parts (+39.0%), precision instruments (+26.3%), and commercial equipment (+23.9%). The time period represented by this analysis was a period of rapid growth.

The analysis surmised that the effect of a water shortage on businesses would be felt most by very large and very small firms. Very large firms (large multi-location corporations) would probably switch operations to locations outside of Orange County during periods of water supply unreliability to the extent other local resources can be found elsewhere. Very small firms would possibly be at the greatest risk for going out of business because they probably do not have the financial reserves to weather an extended shutdown or slowdown of operations.

It was also stated that manufacturing and tourism would most likely suffer the greatest direct negative effects. Some operations could be hampered if water supplies and/or wastewater service was not available through impacts on rooftop cooling towers that use water, temperature controlled lab environments, and manufacturing that requires large quantities of water as an input into production.

Tourism would suffer as the loss of water drives away visitors, slows convention bookings, and creates a negative image for Orange County. Businesses would have to close if they could not provide running water for sinks, toilets, and drains for restrooms. They would also close if they did not have adequate water pressure for sprinkler systems.

The Orange County analysis indicated a WTP that ranged from $11.16 to $17.30 per household per month in 1993 dollars, or $16.56 to $25.68 in 2014 dollars. The lower bound estimate is based on a 20% shortage 1 in 30 years while the upper bound estimate represented a 50% shortage 1 in 20 years. The analysis also indicated that a 5% water reduction for a drought with a 1 to 3 year duration would lead to a decrease in revenues of $6.73 billion to $20.18 billion in 2002 dollars, or $8.52 billion to $25.56 billion in 2014 dollars. A 20% water reduction would lead to a decrease in revenues of $20.44 billion to $61.31billion in 2002 dollars, or $25.88 billion to $77.65 billion in 2014 dollars. Employment impacts for the same drought event were estimated to range from 63,365 to 190,094 jobs and the impacts for a 20% reduction would be a decrease in 192,708 to 578,123 jobs.

The Orange County study provides summary statistics from survey responses to questions regarding how different sectors would respond to a 60% reduction in water supplies over a two month period. The manufacturing sector indicated a 19% reduction in output from a 60% reduction in water supplies, the service sector would experience a 20% reduction in output, the construction sector would have a 23% reduction in output, the wholesale sector would have a 13% reduction in output, and the finance and real estate sector would experience a 5% reduction in output. These survey responses all indicate a significant value for water supply reliability by commercial establishments.

Griffin and Mjelde Study

Griffin and Mjelde (2000) estimated the WTP for a hypothetical increase in water supply reliability or the willingness to accept payment (WTA) for a hypothetical decrease in reliability for seven Texas cities. The mean WTP for sample mean data was $8.47 per household per month and the predicted WTP from the model was $9.76 in 1995 dollars. The mean WTA for the sample mean was $12.66 and predicted WTA was $13.20 in 1995 dollars. Indexing these values to 2014 dollars using the Implicit Price Deflator for personal consumption expenditures results in a WTP of $12.06 to $13.90 and a WTA of $18.03 to $18.80 per household per month in 2014 dollars. WTA is expected to be higher than WTP for two basic reasons. First, WTA is not bound by income as a constraint while WTP is bound by available disposable income. Second, WTA represents a change to a less desirable level of utility or satisfaction which would generally be avoided by consumers. The improvement in conditions associated with WTP may be from a level of utility that is acceptable and would not be valued as highly as a decrease in utility to a level that might not be very acceptable without compensation

The estimates of the value of water supply reliability for Texas would probably be expected to be somewhat less than reliability values in California due in part to

lower population density and as a result somewhat less pressure on water supplies in Texas. The population density for California in 2010 was 239.1 persons per square mile compared to 96.3 persons per square mile in Texas. The value of WTP for improved reliability in the Barakat and Chamberlin California study was $16.52 to $25.13 in 2014 dollars. The Texas based WTP estimates are 55% to 73% of the California estimates.

Koss and Khawaja Study

A study by Koss and Khawaja (2001) estimated mean monthly willingness to pay in ten California water districts to range from $11.67 per household per month (a 10% shortage every 1 out of 10 years) to $16.92 per household per month (a 50% shortage 1 out of every 20 years) in 1993 dollars, depending on the assumed shortage (as a % reduction from full service) and frequency of occurrence (ranging from a 1 in 3 event to a 1 in 30 event). WTP ranges from $17.32 to $25.11 in 2014 dollars. Koss and Khawaja (2001) compare their results to an earlier study by Carson and Mitchell (1987) completed for The Metropolitan Water District of Southern California. The Carson and Mitchell study estimated an annual willingness to pay to avoid various shortage percentages at different intervals. The range of estimated willingness to pay was $83 to $258 annually per household in 1987 dollars. The estimated willingness to pay per household based on the Carson and Mitchell study results ranges from about $12.60 to $39.20 per month in 2014 dollars.

Goddard and Fiske Study

In another study of drought impacts, Goddard and Fiske (2005) estimated the impacts and degree of hardship that water shortages impose on municipal water systems. The study was conducted for Santa Cruz, California and evaluated the potential impacts from water supply shortages impose on municipal water systems. The study evaluated the potential impacts from water supply shortages of 10% to 60% compared to a full supply. The survey included about 1,900 commercial business accounts and 45 industrial accounts. The study indicated a wide variation in production impacts associated with various water supply shortages. The study indicated that the production impacts from a 15% reduction in water supplies varied considerably from business to business. Initial water use reductions were relatively easy to achieve because the least productive water uses will initially be eliminated and revenue losses will be relatively small. Important exceptions indicated in the study included the semiconductor industry, greenhouse and landscaping industries, and restaurants.

The Goddard and Fiske study also indicated that a 25% reduction in water deliveries to business and industrial water users would lead to a significant reduction in output, averaging about 20% across all sectors. Retailers and restaurants would be particularly hard hit. More affected sectors would include smaller hotels and motels, large semiconductor design firms, and potentially community facilities. Semiconductor manufacturers would also suffer. The surveys also indicated 60% of the respondents said non-economic hardships were considerable or extreme and small businesses would be most adversely affected.

A 35% shortage in water supplies to business and industry would result in an average revenue loss across all businesses in excess of 30%, an approximately proportional change in output resulting from a water shortage relative to a full water supply. The losses would be greater for restaurants and retailers. The surveys indicated 50% of non-economic hardships were characterized as "extreme." A summary is presented in Table 3 below.

Table 3: Impact of Various Levels of Water Shortage on Businesses

Extent of shortage	Shortage Percentage	Business Impact[1]
Business Shortage		
Mild	4%	1
Moderate	13%	2
Serious	22%	4
Severe	27%	4-5
Critical	33%	6
Extreme	48%	6
Industrial Shortage		
Mild	5%	2
Moderate	15%	3
Serious	25%	5
Severe	30%	5
Critical	35%	6
Extreme	50%	6

Business Impact[1]
1 = Little or no impacts (0% reduced revenue)
2 = Some impact (5% reduced revenue)
3 = Intermediate impact (15% reduced revenue)
4 = Considerable impact (25% reduced revenue)
5 = Major impact (33% reduced revenue)
6 = Catastrophic impact (100% reduced revenue)

Converting Retail Values to Wholesale Values

The above estimates of the value of water reliability represent benefits at the retail level, where a treated supply is provided at the tap. However, water supply reliability benefits associated with conserved stormwater would be at the base supply or wholesale level. The value (price) of treated water delivered to the point of final use at the retail level will generally be substantially higher than the value of raw water at the wholesale level as will the associated benefit or value of the water supply. Therefore, water supply benefits measured in terms of increased reliability to commercial, industrial, and residential water users will overstate concept benefits.

One approach that can be used to estimate the percentage of total value attributable to the wholesale portion of water supplies is to estimate the water supply costs that are necessary to provide retail service once base supplies are obtained. These retail related costs are primarily related to the treatment and distribution of municipal

water. Expenditures associated with these two aspects of supplying water are the primary difference between retail and wholesale water supplies. Estimating the exact treatment and distribution costs for different water suppliers at different times of the year is not feasible at the appraisal-level. However, general municipal water supply cost information can be used to estimate the percentage of water supply costs that are attributable to providing water at the retail level and the difference between total cost and retail related costs can be assigned to wholesale level supplies. The estimated percentage can then be used as a proxy of the value attributable to wholesale water supplies.

A survey of community water systems by the U.S. Environmental Protection Agency (EPA, 2009) provides estimates of the percentages of water supply costs attributable to different aspects of providing water service. These cost percentages are estimated in the 2009 EPA report for purchased water, security, depreciation, income taxes, payments to general and reserve funds, other routine operating expenses, debt service, land, water source, transmission and distribution systems, treatment, and storage. The EPA survey also asked each participating utility about capital expenses over the five year period prior to the survey. It is assumed that water treatment and distribution costs are associated with providing retail water service. At least a portion of all other expenses are assumed to be attributable to wholesale service costs. The percentage of total expenses associated with different expense categories are shown in Table 4.

Two categories of expenses shown in Table 4 are considered to be entirely part of the cost of providing wholesale water supplies: purchased water and security. The other seven categories of costs include a wholesale component, but the proportion of the cost attributable to wholesale supplies is not known.

Table 4: Water Supply Expenses by Category as a Percentage of Total Expenses

Expense Category	Percentage of Total Costs
Purchased Water	8.9%
Security	0.4%
Depreciation	5.0%
Income Taxes	1.2%
Payments to General Fund	0.4%
Payments to Reserve Funds	2.6%
Other Routine Operating Expenses	65.7%
Debt service	8.5%
Capital Improvements	7.3%

Source: U.S. Environmental Protection Agency, Office of Water. 2006 Community Water System Survey, Volume II: Detailed Tables and Methodology. EPA 815-R-09-002, May 2009.

The capital improvements component of expenditures shown in Table 4 is further broken down in the 2009 EPA report into seven expenditure categories, including

transmission and distribution systems costs and treatment costs. The percentage of total capital expenditures attributable to each expense category is shown in Table 5.

Table 5: Capital Related Expenses by Category as a Percentage of Total Capital Expense

Capital Related Expense Category	Percentage of Capital Expense
Land	1.3%
Water Source	8.7%
Transmission and Distribution Systems	45.9%
Treatment	24.4%
Storage	8.7%
Security	0.5%
Other	10.5%

Source: U.S. Environmental Protection Agency, Office of Water. 2006 Community Water System Survey, Volume II: Detailed Tables and Methodology. EPA 815-R-09-002, May 2009.

The capital related expense percentages for transmission and distribution system and treatment costs equal 70.3% of total capital costs, so 29.7% of costs represent wholesale expenses. Assuming this percentage also applies to expenditures in Table 4 that contribute to both retail and wholesale costs, the portion of all costs attributable to wholesale supplies can be estimated. The derivation of these percentages is shown in Table 6.

Table 6: Impact of Water Shortages on Output

Expense Category	Total Expense	Wholesale Factor	Wholesale Portion
Purchased Water	8.90%	1	8.90%
Security	0.44%	1	0.44%
Depreciation	5.00%	0.297	1.49%
Income Taxes	1.20%	0.297	0.36%
Payments to General Fund	0.40%	0.297	0.12%
Other Routine Operating Expenses	65.70%	0.297	19.52%
Debt Service	8.50%	0.297	2.53%
Payments to Reserve Funds	2.60%	0.297	0.77%
Land	0.09%	1	0.09%
Water Source	0.63%	1	0.63%
Transmission and Distribution System	3.35%	0	0%
Treatment	1.78%	0	0%
Storage	0.64%	0.297	0.19%
Other	0.77%	0.297	0.23%
Total	**100.00%**	**-**	**35.27%**

Based on the data provided in the 2009 EPA report and the assumptions discussed above regarding expenses attributable to supplying water at wholesale level,

approximately 64.73% of water supply expenses for all systems are attributable to distribution, transmission, and treatment of water. The remaining 35.27% of final water supply costs are attributable to the raw water supply and provision costs, which is representative of wholesale costs. It should be noted that the percentages presented in Tables 4, 5, and 6 are representative of all systems combined. The distribution of costs would likely vary by type of system and system size.

Converting Estimated Stormwater Conserved or Stored into Potential Households Served

The Task 2 Report estimated the population of the study area watershed to be 9,607,600 people in 2010 and was projected to be 10,874,300 people in 2035 and 11,500,600 people in 2095. The 2035 population projection is used in this analysis to represent water conservation/storage benefits over the 50-year analysis period used in the economic analysis. The Census Bureau 2009 to 2013 American Community Survey (ACS) 5-year estimates an average household size of 3.01 people for Los Angeles County. Using the estimated number of people per household from the 2009 – 2013 ACS, there would be a projected 3,612,724 households in the watershed by 2035.

Water consumption rates used in the Task 2 Study were a current rate of 138 gallons per capita per day (gpcd) and a 2035 rate of 100 gpcd. A use rate of 138 gpcd combined with an average household size of 3.01 people translates into average water use of 0.465 acre-feet per household per year. A use rate of 100 gpcd translates into 0.337 acre-feet per household per year. Therefore, it is estimated that one acre-foot of water conserved or stored could potentially support 2.97 households for one year by 2035, an increase from only 2.15 households currently.

Calculation of Water Supply Reliability Benefits

Water reliability benefits would be expected for both residential water users and commercial water users, and the previous studies reviewed and discussed above address both sectors of use. However, the benefits estimated for residential water users are described in terms of dollar values per household for varying levels of shortage while commercial/industrial benefits are described more in terms of changes in output or revenues resulting from water shortages or the relative damages of water shortages on businesses. Therefore, the household based values are used to estimate water supply reliability benefits.

It should be noted that the use of benefits transfer assumes that the value of water in the study area is similar to the values derived from previous studies. Overall water supply and demand conditions, and therefore the price and value of water may be very different than what existed when these studies were conducted. Indexing values to the current time period would not capture changes in specific water market conditions, but would simply account for overall general inflation. The estimated household water supply reliability benefits estimated from the previous studies reviewed and the values adjusted to the wholesale level are presented in Table 7.

Table 7: Estimated Water Supply Reliability Benefits Potentially Applicable to the Study Area

Source of Benefit Estimate	Estimated Annual Reliability Benefit per Household at the Retail Level (2014 $'s)		Estimated Annual Reliability Benefit per Household at the Wholesale Level (2014 $'s)	
	Low	High	Low	High
Barakat & Chamberlin, 1994	$198	$302	$70	$107
Carson & Mitchell, 1987	$151	$470	$53	$166
Grifin & Mjelde, 2000	$145	$167	$51	$59
Koss & Khawaja, 2001	$208	$301	$73	$106
Orange County Business Council, 2003	$199	$308	$70	$109

A wide range of reliability benefit estimates are presented in Table 7 representing different levels of shortage occurring with different levels of frequency. The average of all high and low estimates presented is about $245 annually per household. A range of potential benefits is estimated based on the lowest wholesale value of $51 annually per household and the highest wholesale value of $166 per household.

The Grifin and Mejelde study (2000) is based on Texas data and the Barakat and Chamberlin study results showed some inconsistency in the willingness to pay results as the potential severity and duration of shortage varied. It should be noted that the Orange County Business Council (2003) analysis was based on the Barakat and Chamberlin study data. The Carson and Mitchell (1987) study is dated compared to the other studies and it would be preferable to have more recent estimates. The Koss and Khawaja study (2001) is based on data obtained from California urban water agencies and the lower bound estimate represents the willingness to pay to avoid a 1 in 10 year occurrence of a 10% shortage. The Koss and Khawaja study lower bound estimate of willingness to pay was judged to be potentially the most representative of potential water reliability benefits in the region and is the basis for the "best" estimate of benefits. The "best" estimate also uses the mid-point of the range of estimated water conserved or stored. The estimated annual benefits for each project concept are shown in Table 8.

The information presented in Table 8 is used to estimate the present value of water reliability benefits over a 50 year period of analysis. A discount rate of 3.125% was used, which is the current Fiscal Year 2016 federal project planning rate used for water resource projects. The results are shown in Table 9.

The values per acre-foot of water presented in Table 9 are equivalent to a value of $110 to $493 per acre-foot and the best estimate is an equivalent of $182 per acre-foot using the range of acre-feet conserved or stored estimated in Task 5. As a check for the potential accuracy of these estimates, they were compared to water supply values used in three California studies. A study of economic losses due to water scarcity in California (Jenkins, Lund, and Howitt, 2003) estimated these losses, which can be interpreted as a benefit from avoiding scarcity, as ranging from

$600 to $800 per acre-foot in 1995 dollars. Indexing this range of values from 1995 to 2014 using the general urban Consumer Price Index, the range of values would be $930 to $1,240 per acre-foot. This represents a retail value to end water users. Adjusting this value using the same conversion factor of 35.27% used for the estimated reliability values, results in a range of $328 to $437 per acre-foot, which is within the range of benefits estimated in this Task 6 analysis.

A Nature Conservancy study of water supply benefits from forest restoration in the northern Sierra Nevada (Podolak, et al., 2015) used an urban municipal and industrial water value of $150 per acre-foot. This represents a supply value directly comparable to the water reliability benefit estimates in the Task 6 analysis. Finally, an analysis of the benefits from the Bay Delta Conservation Plan (Sunding, et al., 2013) estimated urban water supply benefits to range from about $116 to $130 per acre-foot. The range of benefits in each of these two studies is within the range used in the Task 6 analysis.

Table 8: Estimated Annual Water Supply Reliability Benefits of Los Angeles Basin Concepts

Concept	Households Potentially Supported by Stormwater Conserved at 138 gpcd		Households Potentially Supported by Stormwater Conserved at 100 gpcd		Annual Value of Stormwater Conserved at $51 per Household per Year, 138 gpcd, and Low Estimate of Stormwater Conserved	Annual Value of Stormwater Conserved at $166 per Household per Year, 100 gpcd, and High Estimate of Stormwater Conserved	Annual Value of Stormwater Conserved at $73 per Household per Year and Mid-point of Conservation and Water Use Range
	Low	High	Low	High	Low Estimate	High Estimate	Best Estimate
Local Solutions							
Local Stormwater Capture	38,471	62,971	53,091	86,902	$1,962,000	$14,425,800	$4,576,100
Low Impact Development	174,945	282,834	241,428	390,319	$8,922,200	$64,793,000	$20,632,100
Complete Streets	58,673	93,060	80,970	128,426	$2,992,300	$21,318,700	$6,829,100
Regional Solutions							
Regional Stormwater Capture	56,094	128,737	77,411	177,660	$2,860,800	$29,491,600	$8,532,000
Stormwater Conveyance Systems	17,194	21,492	23,728	29,660	$876,900	$4,923,500	$1,710,100
Alternative Capture	8,167	14,829	11,271	20,465	$416,500	$3,397,200	$1,045,100
Storage Solutions							
LACFCD Dams	123,364	567,603	170,246	783,308	$6,291,600	$130,029,100	$33,093,500
USACE Dams	8,167	25,361	11,271	34,998	$416,500	$5,809,700	$1,575,500
Debris Basins	193	494	267	682	$9,900	$113,200	$32,000
Management Solutions							
Stormwater Policies	333,770	505,061	460,612	696,998	$17,022,300	$115,701,700	$37,623,100
Green Infrastructure Programs	228,675	369,232	315,577	509,550	$11,662,400	$84,585,400	$26,945,200
Regional Impact Programs	46,853	79,305	64,658	109,444	$2,389,500	$18,167,600	$5,704,800

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Table 9: Estimated Present Value of Water Supply Benefits for Each Concept

Concept	Present Value of Water Reliability Benefits Over the 50-Year Period of Analysis Discounted at 3.125%		
	Low Estimate (millions)	High Estimate (millions)	Best Estimate (millions)
Local Solutions			
Local Stormwater Capture	$49	$363	$115
Low Impact Development	$224	$1,628	$519
Complete Streets	$75	$536	$172
Regional Solutions			
Regional Stormwater Capture	$72	$741	$214
Stormwater Conveyance Systems	$22	$124	$43
Alternative Capture	$11	$85	$26
Storage Solutions			
LACFCD Dams	$158	$3,268	$832
USACE Dams	$11	$146	$40
Debris Basins	$0.20	$3	$1
Management Solutions			
Stormwater Policies	$428	$2,907	$946
Green Infrastructure Programs	$293	$2,126	$677
Regional Impact Programs	$60	$457	$143

Potential Recreation Benefits

The Task 5 Report provides estimates of the miles of additional trails provided by each concept. In order to estimate the potential benefits associated with these trails, two pieces of information are needed. The first is the number of recreation users that would be supported by these trails; the second is the value per user day associated with trail use.

Information from the U.S. Army Corps of Engineers' Los Angeles River Ecosystem Restoration Integrated Feasibility Report (2015) is used to estimate the average number of users per trail mile. The Recreation Analysis Appendix indicated an average trail use per mile of 22,490 users annually. This value applied to use without or with a proposed project. This annual use value is applied to the miles of trails added by each concept.

A recreation use values database for North America maintained by the Oregon State University College of Forestry (2015) was used to obtain representative values for trail related recreation in the Los Angeles area. The database contains data from 352 economic valuation studies over the period of 1958 to 2006, totaling 2,703 value estimates for 21 different types of activities. The estimates are measures of net WTP or consumer surplus for recreational access to specific sites or for activities in broader geographic areas.

A study by McCollum, et al. (1990) included sightseeing and general recreation activities in a region that included Los Angeles County. The estimated value per visit in 2010 dollars was estimated to be $16.15 for sightseeing and $7.35 for general recreation. The general recreation activity category is likely to be most applicable to the region because the sightseeing category represents more of a unique experience or destination to see a specific attraction. A confidence interval was provided in the Oregon State University database for general recreation that ranged from $5.04 to $8.76 per visit in 2010 dollars. Given the very general type of recreation represented by additional trails, the lower bound estimate of the confidence interval is used in this analysis. The lower bound estimate is $5.47 per visit in 2014 dollars. Recreation benefits for each of the concepts are presented in Table 10.

Table 10: Recreation Benefits Associated with Additional Trails

Concept	Feet of Trail	Miles of Trail	Annual Increase in Use at 22,480 Visits per Mile	Annual Total Value at $5.47 per Visit
Local Solutions				
Local Stormwater Capture	1,077,000	204.0	4,585,409	$25,082,200
Low Impact Development	0	0	0	$0
Complete Streets	0	0	0	$0
Regional Solutions				
Regional Stormwater Capture	63,000	11.9	268,227	$1,467,200
Stormwater Conveyance Systems	18,018	3.4	76,713	$419,600
Alternative Capture	11,907	2.3	50,696	$277,300
Storage Solutions				
LACFCD Dams	N/A	N/A	N/A	N/A
USACE Dams	N/A	N/A	N/A	N/A
Debris Basins	3,270	0.6	13,922	$76,200
Management Solutions				
Stormwater Policies	0	0	0	$0
Green Infrastructure Programs	0	0	0	$0
Regional Impact Programs	2,782,560	527	11,846,960	$64,802,900

Potential Habitat Benefits, Environmental Values, and Ecosystem Service Values

Indicators of Habitat, Environmental Values, and Ecosystem Services

Ecosystem services can be broadly defined as the benefits obtained as a result of ecosystem functions. The Millennium Ecosystem Assessment (2013) provides four categories of ecosystem services.

- Provisioning Services such as the provision of food and fresh water

- Regulating Services such as climate and disease regulation
- Supporting Services such as soil formation and nutrient cycling
- Cultural Services such as aesthetic and cultural heritage values

Examples of specific services provided within these categories would include carbon sequestration, water purification, ground and surface water flow regulation, erosion control, stream-bank stabilization, species preservation, and recreation/tourism (USDA, 2014).

One important concern associated with estimating the benefits associated with ecosystem services is determining the value that should be placed on the various services. Some of the services represent activities that can be valued using traditional types of economic analyses, such as recreation and water supply. Other types of services, such as species preservation, require sophisticated approaches such as contingent valuation to estimate value. One indicator of the value of ecosystem resources is the cost of infrastructure investments that would be required to provide those services, which can then be compared to the cost of protecting an ecosystem. Some market based values can also indicate value, such as private payments and public incentives to protect ecosystem services.

Other important technical issues in evaluating ecosystem benefits have been identified (Fischenich, et al., 2013). One important issue is assessing the relationship between how activities affect the environment and the ecological response to that change. If the effect of an environmental change on ecosystem services is not known, then it is impossible to value the benefits of the change. A second issue is selection of a quantifiable resource property to measure change, such as wetland acreage. Without this metric, the quantity that should be multiplied by unit values is not known and benefits cannot be quantified.

Accurate measurement of these ecosystem benefits is not possible at an appraisal-level because the relationship between the effects from the concepts and ecosystem services is unknown. However, previous research can provide some general information on the value of different types of ecosystem services for different geographical and biological areas. A summary of ecosystem services values as measured by willingness to pay are presented in Table 6 (Executive Office of the President, 2011). The range of potential ecosystem benefits shown in Table 11 is wide, indicating the importance of knowing the conditions that exist at a specific site.

Table 11: Range of Estimated Willingness to Pay for Ecosystem Services

Biome	Minimum $/acre/year				Maximum $/acre/year			
	Pro-visioning	Cultural	Regulating	Habitat	Pro-visioning	Cultural	Regulating	Habitat
Inland Wetlands	$1	$262	$130	$4	$3,929	$3,399	$9,315	$1,405
Rivers & Lakes	$473	$123	$123	$0	$2,338	$1,106	$2,014	$0
Woodlands	$3	$0	$4	$0	$349	$0	$440	$0
Grasslands	$96	$0	$24	$0	$289	$4	$837	$121

Source: Executive Office of the President, July 2011.

A report by Patton, et al. (2012) provided approaches and estimates for ecosystem service benefits for four wildlife refuges in North Dakota, Maryland, Georgia, and New Mexico. Although none of the refuges are in California, the New Mexico refuge included in the study was the Sevilleta and Bosque del Apache National Wildlife Refuges (NWRs) which can provide an understanding of the magnitude of potential benefits associated with ecosystem services provided in the southwestern United States.

The analysis by Patton, et al. provides estimates of gross economic values for four different types of services: storm protection, water quality, commercial fishing habitat, and carbon storage. The estimated values for Sevilleta and Bosque del Apache NWRs are shown below in Table 12.

Table 12: NWR Ecosystem Service Values

Type of Service	Value per Acre
Storm Protection	$47
Water Quality	$80
Commercial Fishing Habitat	$0
Carbon Storage	$14
Total All Services	**$141**

The overall goal of the research was to develop an ecologic-economic simulation model that can be used to evaluate economic value of ecosystem services supported by NWRs. The model would provide a way to evaluate ecosystem services when primary data studies are not possible due to funding and/or time constraints. This describes the situation for the evaluation of LA Basin Study concepts very well. It should also be noted that although the models are applied to NWRs, the values are for ecosystem services *provided* by NWRs and are not exclusive only to NWRs. The values for storm protection, water quality, and habitat, and nursery support for commercial fishing species were estimated using meta-analysis benefit transfer while carbon storage benefits are based on point estimate benefit transfer from studies on the willingness to pay to avoid climate change damages.

Potential Habitat and Ecosystem Benefits of the Concepts

A range of habitat benefits was estimated using the $141 per acre value from the NWR study by Patton, et al. (2012), the $719 value for rivers and lakes from the

Executive Office of the President (2011) analysis, and the estimated habitat acreage associated with each concept plan. Additional habitat related benefits were estimated for the Regional Impact Programs to account for right-of-way acreage where concrete would be removed and replaced with an earthen low flow channel. The benefits generated for this acreage would not necessarily be equal to the full benefits used for habitat acreage, but there is no non-arbitrary method for separating out these benefits, so full habitat benefits were attributed to the Regional Impact Programs right-of-way acreage. The results are shown below in Table 13.

Table 13: Benefits Associated with Habitat and Right-of-Way Acreage

Concept	Habitat Acres	Existing Right-of-Way Acreage converted	Combined Acreage	Combined Annual Value at $141 per Acre	Combined Annual Value at $719 per Acre
Local Solutions					
Local Stormwater Capture	266	0	266	$37,500	$191,300
Low Impact Development	0	0	0	$0	$0
Complete streets	0	0	0	$0	$0
Regional Solutions					
Regional Stormwater Capture	42	0	42	$5,900	$30,200
Stormwater Conveyance Systems	8	0	8	$1,100	$5,800
Alternative Capture	2	0	2	$300	$1,400
Storage Solutions					
LACFCD Dams	0	0	0	$0	$0
USACE Dams	0	0	0	$0	$0
Debris Basins	0	0	0	$0	$0
Management Solutions					
Stormwater Policies	0	0	0	$0	$0
Green Infrastructure Programs	0	0	0	$0	$0
Regional Impact Programs	5,200	2,470	7,670	$1,081,500	$5,514,700

Quantified Economic Benefits and Costs

Economic benefits were quantified for water supply reliability, recreation associated with trail use, and habitat and right-of way acreage in terms of potential environmental benefits. The Task 5 Report presented costs in terms of capital, land, and annual operation and maintenance costs. The present value of quantified benefits and costs are presented in Table 14 and Table 15. Costs are not indicated for the USACE Dams because cost estimates were not presented for separate values

of capital, land, and operation and maintenance costs for this concept, so comparable costs could not be calculated for the USACE Dams. The information presented in Tables 14 and 15 can be used by decision makers to evaluate the relative magnitudes of quantified benefits and costs associated with each concept.

Table 14: Best Estimate of Benefits and Costs over the 50-Year Period of Analysis Associated with Project Concepts

Concept	Present Value of the Best or Mid-point Estimate of Quantified Benefits (millions)	Present Value of Capital, Land, and Operation & Maintenance Costs (millions)
Local Solutions		
Local Stormwater Capture	$748	$7,153
Low Impact Development	$519	$21,055
Complete Streets	$172	$12,253
Regional Solutions		
Regional Stormwater Capture	$252	$1,320
Stormwater Conveyance Systems	$54	$10,346
Alternative Capture	$34	$226
Storage Solutions		
LACFCD Dams	$832	667
USACE Dams	$40	N/A
Debris Basins	$3	$74
Management Solutions		
Stormwater Policies	$946	$227,362
Green Infrastructure Programs	$677	$26,681
Regional Impact Programs	$896	$116,661

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Table 15: Benefits and Costs Associated with Project Concepts

Concept	Present Value of Water Reliability Benefits over 50 Years (million $'s)		Present Value of Recreation Benefits over 50 Years (million $'s)	Present Value of Habitat and Right-of-Way Acreage over 50 Years (million $'s)		Range of Present Value of Benefits (million $'s)		Capital and Land Acquisition cost (million $'s)	Present Value of Operation and Maintenance Costs over 50 Years (million $'s)
	Low	High		Low	High	Low	High		
Local Solutions									
Local Stormwater Capture	$49	$363	$630	$10	$53	$690	$1,046	$4,414	$2,739
Low Impact Development	$224	$1,628	$0	$0	$0	$224	$1,628	$9,696	$11,359
Complete Streets	$75	$536	$0	$0	$0	$75	$536	$5,970	$6,283
Regional Solutions									
Regional Stormwater Capture	$72	$741	$37	$3	$13	$111	$791	$993	$327
Stormwater Conveyance Systems	$22	$124	$11	$0	$1	$33	$135	$7,154	$3,192
Alternative Capture	$11	$85	$7	$0	$1	$18	$93	$152	$74
Storage Solutions									
LACFCD Dams	$158	$3,268	$0	$0	$0	$158	$3,268	$249	$418
USACE Dams	$11	$146	$0	$0	$0	$11	$146	NA	NA
Debris Basins	$0	$3	$2	$0	$0	$2	$5	$41	$33
Management Solutions									
Stormwater Policies	$428	$2,908	$0	$0	$0	$428	$2,908	$20,4443	$22,919
Green Infrastructure Programs	$293	$2,126	$0	$0	$0	$293	$2,126	$12,508	$14,173
Regional Impact Programs	$60	$457	$630	$10	$53	$701	$1,140	$98,643	$18,018

Trade-Off Analysis

A trade-off analysis consists of essentially three different problems:

1. A sorting problem, which identifies the alternatives or concepts that meet specific minimum criteria.
2. A ranking problem, which compares alternatives or concepts that meet specific minimum criteria.
3. A choice problem, which addresses the question of which alternatives or concepts are best given specific identified criteria.

It is the third problem that is primarily addressed in this analysis since identification of concepts that best meet the goals of the region was part of the Task 5 Report. The end goal of the Task 6 analysis is to identify a concept or group of concepts that results in the best possible outcome given several desired outputs, some of which may be conflicting. An important step in completing a trade-off analysis is to obtain measures of outputs that are most important to the region that can then be compared across concepts. Ideally these outputs will be quantified in units that represent relative values for different categories of benefits. This step is highly dependent on outputs identified and measured as part of Task 5. Once these output measures are obtained, a method must be used to weigh the importance of each output measure and compare the set of outputs obtained from each concept. This is the heart of the trade-off analysis.

Measures Included in the Trade-Off Analysis

In order to arrive at the best possible result or range of results, a judgement must be made regarding the relative desirability of identified criteria. This decision is fairly straight-forward in a traditional economic analysis, where all relevant effects are translated into monetary terms which are directly comparable and can be added together into a meaningful result. However, when considering a range of effects that cannot be expressed entirely in monetary terms, a process is needed to convert all of the effects into comparable measures.

Answering the choice problem requires specific elements or measures to be identified as important issues that should be addressed by the alternatives or concepts that are under consideration. One of the primary goals of the LA Basin Study is stormwater conservation. However, there are several additional benefit categories that can be supported by a stormwater conservation project as well.

Five basic elements (including stormwater conserved) were identified as part of the Task 5 Report. These five elements included:

- Stormwater conserved or increased storage capacity, measured in acre-feet per year
- Recreation, measured in miles of new trail
- Habitat, measure in new acreage
- Right-of-way, measured in new acreage acquired
- Range of Costs, including capital costs and recurring operation and maintenance costs

These five elements clearly need to be included as part of the trade-off analysis given their inclusion in the Task 5 Report. Right-of-way impacts can be thought of as potentially positive environmental and aesthetic impacts, essentially similar to open space.

Additional potential elements were identified based on a review of triple bottom line (TBL) analysis tools (for example, Hammer, et al., 2015) and input from the Stakeholder Technical Advisory Committee (STAC). A TBL analysis includes social, environmental, and economic/financial effects of a project or policy/regulation and provides a more complete assessment of effects than a traditional economic analysis. Six performance areas were identified by Hammer, et al. (2015).

1. Industry Eco-Efficiency – Includes energy and water use, the creation and disposal of solid waste, and air and water quality.
2. Green Design and Construction – Includes avoidance of sensitive natural resources and restoration and conservation of natural resources.
3. Green Operations – Includes consideration of energy use, energy sources, emissions, and the use of green products.
4. Place-making and Accessibility – Includes access to cultural and recreational resources, access to transportation, and access to affordable housing.
5. Environmental Conditions and Human Health.
6. Governance – Includes prevention and mitigation of population displacement, stakeholder involvement, and accountability for project impact.

Elements included in these six performance areas were used as a first list of potential measures to include in the trade-off analysis presented to STAC members. These measures and definitions of impacts were included in a survey, which asked for a ranking of importance for 19 different impact measures. STAC members were asked to rank each element in terms of importance on a scale of 1 to 10, with 1 representing a low importance and 10 representing a high importance. The impact measures and definitions are presented in Table 16.

Survey responses were received from 24 STAC members and represented a diverse group of regional interests. The 1 to 10 rankings for the 19 impact categories were normalized between 0.0 and 1.0 for each survey. For example, if the highest score from an individual survey was an 8, this score would represent the highest possible score for that survey. The normalized score would then be 8÷8 or 1.0. For another category on that same survey, if a score of 4 was assigned, the normalized score would become 4÷8 or 0.5. In this way the maximum normalized score for a category would be a 1.0 for all participants, resulting in all survey respondents having an equal influence on the total weighted score. The same process is used to derive a weighted score for each category across all survey participants, where the maximum score is the base used to normalize each impact category. The average of normalized individual importance scores and the normalized average importance scores are shown in Table 17. Both scores are shown to indicate the impact of the normalization process on the weighting factors. The normalized average scores are 3.87% to 4.06% higher than the average of the individual scores, so there is little relative difference between the two. The normalized average importance scores are used in the trade-off analysis.

Table 16: Impact Categories and Definitions Included in the Survey of STAC Members

Impact Category	Impact Category Definition
Stormwater Conservation	The annual amount of stormwater recharged, captured, conserved, or stored, and made available for future water supply by implementing a concept.
Capital Cost	The initial planning, design, and construction costs of a concept.
Operations & Maintenance Cost	The running upkeep cost for a concept.
Habitat	The land area set aside for new habitat acreage or improvement to existing habitat within the footprint of a concept.
Recreation	The land area set aside for recreational improvements (bike ways, trails, or greenways) within the footprint of a concept.
Climate Adaptation	The ability of a concept to readily adapt to the effects of climate change.
Flood Risk Mitigation	The ability of a concept to mitigate flood risk or flood damages during a storm event.
Regional Economic Impact	The changes to income, employment, and value of goods and services produced in a region, including impacts on fiscal/government (federal, state, or local) revenues, expenses, and services after implementing a concept.
Financial Impact	Changes in business and household costs and budgets after implementing a concept.
Environmental Compliance and Regulatory Permitting	The level of permitting and environmental compliance required for a concept.
Water Quality Impact	The change in water quality after implementing a concept.
Pollutant & Environmental Impact	The change in waste and pollutant production associated with implementing a concept. This includes changes in pollution to the natural and built environment (e.g., air, soil, water, solid waste). Additionally, this includes changes to greenhouse gas emissions from materials development, during construction, and over the lifecycle of the concept.
Energy Impact	The changes in use of various energy sources from implementing a concept. Energy categories include electricity, fossil fuels, and natural gas.
Endangered Species	The level of effort required to avoid adverse impacts to endangered species, threatened species, or species of concern when implementing a concept.
Ecosystem Function	The changes in the interactions between organisms and the physical environment, such as nutrient cycling, soil development, and water budgeting.
Connectivity	The change in the degree to which the landscape facilitates movement of people, wildlife movement, and other ecological flows.
Environmental Justice Impacts	The changes to the fair treatment and meaningful involvement of all people (regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies) from implementation of a concept.
Education	The ability of a concept to educate the public and raise awareness of the natural environment, their relationship to water, and its impacts to the region.
Health & Well-Being Impacts	The changes to quality of life, public health, mobility, and physical activity from implementation of a concept.

Table 17: Normalized Ranking of Importance for Measures Included in STAC Survey

Measure	Average of Normalized Individual Importance Scores	Normalized Average Importance Score
Stormwater Conservation	0.96	1.00
Capital Cost	0.60	0.63
Operations & Maintenance Cost	0.65	0.68
Habitat	0.56	0.59
Recreation	0.47	0.49
Climate Adaptation	0.74	0.78
Flood Risk Mitigation	0.74	0.77
Regional Economic Impact	0.51	0.53
Financial Impact	0.44	0.46
Environmental Compliance and Regulatory Permitting	0.52	0.54
Water Quality Impact	0.84	0.87
Pollutant & Environmental Impact	0.71	0.74
Energy Impact	0.61	0.64
Endangered Species	0.52	0.54
Ecosystem Function	0.63	0.66
Connectivity	0.59	0.61
Environmental Justice Impacts	0.62	0.65
Education	0.48	0.50
Health & Well-Being Impacts	0.61	0.64

A correlation analysis was completed for the 24 individual responses to the importance of each impact category to determine if there is redundancy in the impact measures. In other words, if the level of importance of two impact categories is highly correlated for the respondents as a group, then it is possible that the two categories are measuring the same thing. The analysis found that based on statistical significance at the 1% level of simple correlation coefficients, four of the measures were highly correlated with several other variables and were deemed redundant. These redundant measures were discarded from the trade-off analysis. The results of the correlation analysis are summarized in Table 18 and a description of correlated measures is presented in Table 19. For each of the discarded measures, there are at least two correlated measures that are included as a retained measure.

Table 18: Retained and Discarded Measures Based on a Correlation Analysis

Measure	Retain or Discard Measure?	Reason to Retain Or Discard
Stormwater Conservation	Retain	No correlation with other measures
Environmental Compliance and Permitting	Retain	No correlation with other measures
Water Quality	Retain	No correlation with other measures
Capital Cost	Retain	Correlated only with O&M Cost
Operation and Maintenance (O&M) Cost	Retain	Correlated only with Capital Cost
Climate Adaptation	Retain	Correlated only with Energy Impacts
Flood Risk Mitigation	Retain	Correlated only with Health & Well being
Financial Impact	Retain	Correlated and combined with Regional Impacts
Ecosystem Function	Retain	Retained as a measure of several impacts
Habitat	Retain	Retained as a measure of several impacts
Pollutant and Environmental Impact	Retain	Retained as a measure of several impacts
Environmental Justice Impacts	Retain	Retained as a measure of several impacts
Connectivity	Retain	Retained as a measure of several impacts
Recreation	Retain	Retained as a separate measure of a specific activity
Energy Impacts	Retain	Retained as a measure of several impacts
Endangered Species	Discard/Combine	Correlated with 5 variables
Regional Economic Impact	Discard/Combine	Correlated with Financial Impact & Recreation
Education	Discard/Combine	Correlated with 6 variables
Health and Well Being	Discard/Combine	Correlated with 6 variables

Table 19: Description of Measures Correlated to Discarded Measures

Discarded Measure	Correlated Measures
Endangered Species	Habitat, Pollutant and Environmental Impact, Ecosystem Function, Environmental Justice, Education
Regional Economic Impact	Financial Impact, Health & Well-being, Recreation (Combined with Financial)
Education	Health & Well-being, Habitat, Pollutant and Environmental Impact, Energy Impact, Endangered Species, Environmental Justice
Health and Well Being	Recreation, Flood Risk Mitigation, Regional Economic Impact, Connectivity, Environmental Justice, Education

The final list of measures and weights used in the trade-off analysis are shown in Table 20. The weights indicate the relative importance of each category of impact measures and these weights will be assigned to the rankings of each project concept to arrive at a final weighted score for each project concept.

Table 20: Measures and Weights Used in Trade-Off Analysis

Measure	Final Weights Used in Trade-Off Analysis
Stormwater Conservation	1.00
Capital Cost	0.67
Operations & Maintenance Cost	0.72
Habitat	0.63
Recreation	0.55
Climate Adaptation	0.80
Flood Risk Mitigation	0.80
Financial Impact	0.52
Environmental Compliance and Regulatory Permitting	0.59
Water Quality Impact	0.89
Pollutant & Environmental Impact	0.77
Energy Impact	0.67
Ecosystem Function	0.69
Connectivity	0.65
Environmental Justice Impacts	0.68

Assessing the Measures Included in the Trade-Off Analysis

The five elements or measures included in the Task 5 Report, four of which are shown in Table 1 and the fifth of which is project cost, can be assessed using a traditional economic type of analysis and measures of resource impacts, such as acre-feet and acres. Additional qualitative impacts presented in the Task 5 Report and presented in Table 2 can be used to assess flood mitigation effects, climate resilience, aesthetics, and water quality. However, other social and environmental elements require additional information to assess potential magnitudes of effects.

California Communities Environmental Health Screening Tool

Potential effects in the areas of pollutant and environmental impacts, environmental justice, water quality, and connectivity were analyzed using the California Communities Environmental Health Screening Tool (California Environmental Protection Agency, 2014). The primary purpose of the environmental health screening tool (CalEnviroScreen) is to help evaluate potential environmental justice issues. The tool identifies areas that face pollution burdens and populations that are most vulnerable to the effects of pollution.

CalEnviroScreen provides relative rankings of communities based on a select group of available datasets, through the use of a summary score. The CalEnviroScreen score is not an expression of health risk, and does not provide quantitative information on increases in cumulative impacts for specific sites or projects. In addition, CalEnviroScreen does not provide a basis for determining when

differences between scores are significant in relation to public health or the environment. However, CalEnviroScreen does provide a relative measure of impact and provides a resource for evaluating multiple pollution sources and stressors that takes into account a community's vulnerability to pollution.

The CalEnviroScreen model accounts for pollution burden using exposures and environmental effects, and accounts for population characteristics using sensitive populations and socioeconomic factors. CalEnviroScreen uses data related to pollution sources, releases, and environmental concentrations as indicators of potential exposure. Indicators include ozone concentrations, particulate concentrations, diesel particulate emissions, use of specific high hazard pesticides, toxic releases from facilities, traffic density, and drinking water contaminants.

The CalEnviroScreen score is based on pollution burden (exposures and environmental effects) multiplied by the population characteristics (sensitive populations and socioeconomic factors). This approach is based on available scientific literature, risk assessment principles, and established risk scoring systems. The maximum score of 100 is based on a maximum score of 10 for pollution burden and 10 population characteristics. The pollution burdens and populations characteristics included in the CalEnviroScreen score are shown in Table 21.

Table 21: Pollution Burdens and Population Characteristics Included in the CalEnviroScreen Score

Pollution Burden	Population Characteristics
• Ozone concentrations • PM2.5 concentrations • Diesel PM emissions • Pesticide use • Toxic releases • Traffic density • Drinking water contaminants • Cleanup sites • Groundwater threats • Hazardous waste • Impaired water bodies • Solid waste sites and facilities	• Children and elderly • Low birth-weight births • Asthma emergency department visits • Educational attainment • Linguistic isolation • Poverty • Unemployment

This trade-off analysis should be considered an appraisal-level screening analysis of concepts that could be the basis for future alternatives that could be evaluated for feasibility. Therefore, ranking the concepts in terms of vulnerability to environmental and social concerns fits well within the identified purpose of the CalEnviroScreen tool.

Specific Pollution Burdens and Population Characteristics Considered in This Trade-Off Analysis

Three specific pollution burdens and population characteristics were identified as potentially useful in evaluating the impacts of various concepts on the measures included in the trade-off analysis. In addition, the CalEnviroScreen tool provides percentages of ethnic and minority populations.

Groundwater Threats

This is an indicator of activities and conditions that pose a threat to groundwater quality. These threats could include storage and disposal of hazardous materials on the land and in underground storage tanks. The sites could be commercial, industrial, or military sites and the leaked material could be fuels, solvents, volatile organic compounds, heavy metals, pesticides, and other hazardous substances. Information is based on data from the California State Water Resources Control Board (SWRCB) and the indicator takes into account information about the type of site, its status, and its proximity to populated census blocks. A major factor in the weights assigned for groundwater threats is distance to the nearest populated census blocks within a given tract.

Impaired Water Bodies

This indicator is the sum of the number of pollutants across all water bodies designated as impaired within the area. The indicator measures the relative level of compromised water uses such as drinking, swimming, fishing, aquatic life protection, and other beneficial purposes. SWRCB data providing a list of impaired water bodies is the basis for measuring the level of impairment. Lakes, streams and rivers that do not meet water quality standards or are not expected to meet standards are listed as impaired under section 303(d) of the Clean Water Act. For the screening tool the number of pollutants listed in streams and rivers that fell within 1 kilometer (small streams) or 2 kilometers (large streams) of the census tracts population are counted. The same approach was used for large and small lakes, bays, and estuaries. The two pollutant counts were summed for each census tract. The census tract scores are based on the order of summed scores for the combined pollutants. For example, the top 10% of scores have 15 or more pollutants while the top 30% have 10 to 11 pollutants. The scoring represents a relative weight.

Poverty

Poverty is recognized as an important factor that influences health and welfare. The source of data is the 2008 – 2012 American Community Survey (ACS) 5-year estimate. Poverty is defined in terms of income and the number of family members. Poverty is based on thresholds of income, which were adjusted for the CalEnviroScreen tool based on 200% of the federal poverty level. This was to account for the length of time since the federal poverty thresholds have been changed and the relatively high cost of living in California. The data for each census tract was tested for reliability and those that are evaluated as reliable were ordered by the percentage of the population below twice the federal poverty level. A percentile score for a census tract was determined by its place in the distribution

of all census tracts. For example, the top 10% of scores have more than 65% of the population living below twice the federal poverty level while the top 30% have 47% to 55% of the population living below twice the federal poverty level. The scoring represents a relative weight.

Characteristics Used to Represent Impact Measures

The poverty percentages combined with the percentage of non-white population were used as an indicator of potential environmental justice concerns. The overall Cal Environ Score was used as an indicator of connectivity and the pollution burden score was used as an indicator of pollutant and environmental impact. Finally, the average of impaired water and groundwater threat scores were used as an indicator of ecosystem function.

Process Used to Obtain Representative CalEnviroScreen Scores for Concept Areas

CalEnviroScreen scores, and the individual scores that support the overall score, were obtained for each Census Tract included in the identified concepts. The Census Tracts were combined and scores averaged to represent the affected areas. These, combined scores are presented in Table 22.

Estimating Weighted Scores for Individual Concepts

The individual values based on input for project benefits, capital and land costs, operation and maintenance costs, qualitative benefits provided in the Task 5 Report, and the information described above from the CalEnviroScreen tool are combined with the impact measure weights to derive weighted scores for each concept. The measures of resource impacts use the highest score as the base for all other scores. For example, if the concept that provides the greatest amount of habitat acreage provides 500 acres, then 500 acres would be considered to be a “perfect” 100 score. A concept that provides 200 acres would get a score of 40 ([200/500] x 100). Table 23 shows these scores. Finally, the weighted scores for each concept are multiplied by the measures of importance obtained from the survey of STAC members. These results are displayed in Table 24.

Table 22: Population and Environmental Characteristics from CalEnviroScreen 2.0

Concept	Popula-tion	Pollution Burden	Population Characteristics	% White	% Latino	% Asian	% African American	Cal Enviro Score	Impaired Water	Ground-water Threat	Poverty
Stormwater Conveyance											
Bell	28,424	60	56	36	47	12	3	62	29	42	56
Browns	24,603	57	62	29	48	17	4	66	16	31	58
Aliso	25,115	52	60	26	56	13	4	61	42	49	60
Bull	15,591	82	73	29	55	9	6	82	48	23	65
Tujunga	28,817	83	56	35	46	12	4	74	13	60	60
Burbank West	31,326	96	56	54	29	11	3	84	73	99	57
Verdugo	38,573	91	44	63	16	16	1	71	47	76	47
Arroyo Seco	14,194	76	31	67	13	5	5	51	36	4	9
Alhambra	50,315	92	67	6	31	62	0	86	9	96	67
Rubio	29,395	96	63	7	32	59	0	87	0	98	63
Eaton	25,354	99	67	11	43	45	0	90	0	97	58
Rio Hondo	67,735	96	76	9	58	32	0	92	32	84	72
Big Dalton	25,928	95	81	5	82	12	1	96	34	78	73
Walnut	32,886	90	58	13	89	15	3	78	42	40	46
San Jose	53,946	90	48	10	60	27	2	76	28	51	53
LACFCD Dams											
Morris Dam	886	55	23	62	19	5	11	38	42	32	1
Pacoima Dam	546	74	52	56	37	4	0	68	0	75	1
Puddingstone Div.	4,798	58	28	63	25	8	0	43	0	53	12
San Dimas Dam	886	55	23	62	19	5	11	38	42	32	1
San Gabriel Dam	886	55	23	62	19	5	11	38	42	32	1
Cogswell Dam	886	55	23	62	19	5	11	38	42	32	1
Big Tujunga Dam	546	74	52	56	37	4	0	68	0	75	1
USACE Dam	15,971	79	59	32	54	5	8	72	12	32	56
Regional Stormwater Capture											
NSG1	6,848	87	72	23	62	7	7	86	77	13	68
NSG2	5,249	93	33	30	46	16	5	63	0	92	29
NSG3	7,021	90	50	29	41	19	9	73	0	1	42
NSG4	5,446	94	74	42	37	18	0	93	49	79	52
NSG5	7,076	100	61	15	68	11	4	98	15	86	56
NSG6	4,803	49	66	4	82	11	3	63	0	21	68
NSG7	8,426	66	48	46	32	15	4	61	0	19	34
NSG8	3,661	50	36	57	16	18	5	43	0	33	22
Local Solutions											
Generalized Local Solutions	NA	86	61	23	48	27	2	79	29	68	59

Table 23: Concept Scores by Impact Category

Concept	Weighted Scores by Value Measure														
	Storm water	Capital Cost	O&M Cost	Habitat	Recrea-tion	Energy	Flood Risk	Financial Impacts	Envir-onmental Compliance	Water Quality	Pollutant& Envir-onmental Impact	Climate Adaptation	Eco-system Function	Connect-ivity	Envir-onmental Justice
Local Stormwater Capture	12	55	62	63	55	67	100	97	100	100	14	100	52	21	50
Low Impact Development	55	35	36	0	0	67	50	91	100	100	14	100	52	21	50
Complete Streets	18	47	52	0	0	67	50	95	100	100	14	100	52	21	50
Regional Stormwater Capture	22	64	71	10	3	45	0	99	50	100	21	100	70	28	75
Stormwater Conveyance	5	45	62	2	1	67	50	95	100	50	16	100	54	23	0
Alternative Capture	3	66	71	0	1	0	50	100	100	100	16	100	54	23	75
LACFCD Dams	82	99	98	0	0	67	50	100	0	0	39	100	64	53	100
USACE Dam	4	NA	NA	0	0	67	50	NA	0	0	21	100	78	28	100
Debris Basins	0	67	71	0	0	67	50	100	100	50	16	50	54	23	50
Stormwater Policies	100	0	0	0	0	67	0	0	100	100	23	100	61	31	75
Green Infrastructure Programs	71	26	27	0	0	67	50	88	50	100	23	100	61	31	75
Regional Impact Programs	15	53	63	63	55	67	50	49	50	100	21	100	70	28	75

Table 24: Weighted Concept Scores by Impact Category

Concept	Weighted Scores by Value Measure														
	Storm-water	Capital cost	O&M cost	Habitat	Recrea-tion	Energy	Flood Risk	Financial impacts	Envir-onmental compli-ance	Water quality	Pollutant & Envir-onmental Impact	Climate Adaptation	Eco-system function	Connect-ivity	Envir-onmental Justice
Local Stormwater Capture	12	37	45	40	29	45	80	50	59	89	11	80	36	14	34
Low Impact Development	55	23	26	0	0	45	40	47	59	89	11	80	36	14	34
Complete Streets	18	31	37	0	0	45	40	49	59	89	11	80	36	14	34
Regional Stormwater Capture	22	42	50	6	2	30	0	52	30	89	16	80	48	18	51
Stormwater Conveyance	5	30	44	1	1	45	40	50	59	44	13	80	38	15	0
Alternative Capture	3	44	51	0	0	0	40	52	59	89	13	80	38	15	51
LACFCD Dams	82	66	70	0	0	45	40	52	0	0	30	80	45	34	68
USACE Dam	4	0	0	0	0	45	40	0	0	0	16	80	54	18	68
Debris Basins	0	44	51	0	0	45	40	52	59	44	13	40	38	15	34
Stormwater Policies	100	0	0	0	0	45	0	0	59	89	17	80	42	20	51
Green Infrastructure Programs	71	17	20	0	0	45	40	46	30	89	17	80	42	20	51
Regional Impact Programs	15	36	45	40	30	45	40	25	30	89	16	80	48	18	51

Finally, the weighted average score from Table 24 can be averaged or summed to compare each concept considering all of the important impact measures identified by the STAC. These results are shown in Table 25.

Theoretically the maximum average score for a concept is 100 and the maximum sum of scores is 1,500. However, this would only occur for a concept that is the best at every possible category, and this could only occur if there are no trade-offs for this project. A perfect concept does not exist, so the concept scores shown in Table 25 need to be compared on a relative basis.

Table 25: Final Trade-Off Weighted Scores of Concepts

Concept	Final Weighted Scores of Concepts	
	Average Score	Sum of Scores
Local Solutions		
Local Stormwater Capture	44.0	660
Low Impact Development	37.2	558
Complete Streets	36.2	543
Regional Solutions		
Regional Stormwater Capture	35.8	537
Stormwater Conveyance Systems	30.9	464
Alternative Capture	35.6	534
Storage Solutions		
LACFCD Dams	40.9	613
USACE Dams	21.7	326
Debris Basins	31.7	475
Management Solutions		
Stormwater Policies	33.6	504
Green Infrastructure Programs	37.9	568
Regional Impact Programs	40.5	607

Summary and Opportunities

The economic analysis of quantified benefits can be used to evaluate the magnitude of potential benefits of each concept, recognizing that many additional benefits may exist that are not accounted for in a traditional benefit analysis. The economic analysis indicates that the LACFCD Dams project group is the only concept that generates quantified benefits in excess of project costs. The next tier of concepts with benefits that are in the 10% to 20% range of costs are the Local Solutions and the Regional Stormwater Capture concepts. Although these concepts do not generate quantified benefits in excess of costs, they do generate benefits that are greater than the other project groups, except for the LACFCD Dams concept.

It must be noted that the Local Solutions and Regional Solutions concepts generate qualitative benefits that are generally moderate to high, while the Storage Solutions generate low qualitative benefits. Therefore, if these qualitative benefits are targeted as important, then using the quantitative economic benefits and costs as the sole priority measure could lead to an incorrect conclusion.

The trade-off analysis indicates that the Local Solutions, Regional Impact Programs, and Green Infrastructure Programs produce higher value benefits than the other final weighed scored of concepts noted in Table 25. Nevertheless, the results of the trade-off analysis can be evaluated based on individual impact categories to compare impacts that are more relevant and important to specific agencies, organizations, or groups within the region.

The final results of this economic and trade-off analysis should not be used in isolation to evaluate and compare the concepts addressed, but should instead be used as a baseline evaluation that can be adjusted to represent particular resources and impacts of interest. From this analysis, a number of opportunities with high stormwater conservation potential have been explored, most notably: LACFCD Dam Storage Solutions, Local Solutions, Regional Impact Programs, and Green Infrastructure Programs. These opportunities will help water resource planners target areas of interest for future water conservation efforts and climate resiliency within the region.

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