RECLAMATION
Managing Water in the West

Los Angeles Basin Study
The Future of Stormwater Conservation

Task 6 – Trade-Off Analysis & Opportunities

U.S Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

January 2016

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Cover Photo: Morris Dam on the San Gabriel River, Los Angeles County, California.

Los Angeles Basin Study

Task 6 – Trade-Off Analysis and Opportunities

January 2016

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Executive Summary

The Los Angeles Basin 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 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 both 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 issues. The stormwater capture concepts and alternatives developed in the *Task 5 – Infrastructure & Operations Concepts* report are evaluated in 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 and non-quantifiable benefits and costs of the stormwater concepts identified in the Task 5 report and to provide an analysis of the trade-offs among 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 that cannot all be quantified in monetary terms. 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. Environmental effects 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 such as impacts to education, environmental justice, and quality of life.

Benefits are quantified for three categories of resource impacts. The first category is additional stormwater conserved or stored, which is measured in terms of acre-feet per year. The second is recreation, which is measured in miles of new trails. The third is increased habitat acreage and additional acquisition of right-of-way acreage that would provide habitat benefits. 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 an ecosystem improvement. In the case of the Regional Impact Programs concept, right-of-way acreage also produces some ecosystem benefits. Quantified benefits and costs as well as categories of qualitative benefits are summarized in Table ES-1. All benefits and costs are present valued over a 50-year planning period using the current Fiscal Year 2016 federal water project planning rate of 3.125%.

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 and cost analysis. It is important to note that quantified benefits could only be developed for a subset of the total beneficial effects associated with the concepts identified in the Task 5 report. There are many potential benefits associated with environmental and social improvements, flood risk mitigation, environmental justice, and other effects that could be large but cannot be evaluated quantitatively for this level of analysis. These unquantified benefits may be larger than quantified benefits in some cases and smaller in other cases. The intent of the qualitative assessment is to provide an indication of the potential magnitude of unquantified benefits.

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 Best or Mid-point Estimate of Quantified Benefits (millions)	Present Value of Capital, Land, and Operation & Maintenance Costs (millions)
Local Solutions		
Local Stormwater Capture	$787	$8,410
Low Impact Development	$460	$21,055
Complete Streets	$2,056	$12,253
Regional Solutions		
Regional Stormwater Capture	$251	$1,320
Stormwater Conveyance Systems	$54	$10,346
Alternative Capture	$33	$227
Storage Solutions		
LACFCD Dams	$832	$668
USACE Dams	$40	N/A
Debris Basins	$3	$74
Management Solutions		
Stormwater Policies	$3,309	$43,362
Green Infrastructure Programs	$601	$26,681
Regional Impact Programs	$2,424	$97,211

From Table ES-1, the results of the economic analysis indicate the LACFCD Dams concept is the only concept that generates quantified benefits that exceed costs. Stormwater Policies, Regional Impact Programs, Complete Streets, and Local Stormwater Capture generate benefits that are of a higher or similar magnitude as the LACFCD Dams concept, but at a much higher cost. The other concepts generate substantially lower quantified benefits.

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 include items such as flood risk, water quality, aesthetics, heat island mitigation, and climate resiliency. Supplemental information was 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 all local stakeholders or to the general public. To account for the variation in the importance of different effects, a survey of the Basin Study's 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 impact measure to determine a final trade-off score, representing 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, representing the most important impact measure.

Table ES-2. Weights used for Impact Categories in Descending Order of Importance

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 & Regulatory Permitting	5.90
Recreation	5.46
Financial Impact	5.20

The trade-off analysis incorporated information for quantitative and qualitative impacts for each concept and the importance weights based on the STAC survey results to calculate a final score for each concept. All scores prior to weighting are measured relative to the highest scoring concept. This approach allows all quantitative and qualitative effects to be expressed as unitless values that are comparable across the different effects. Higher scores indicate higher combined benefits.

Weights based on the STAC survey are used to compute concept scores. The STAC 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 and Flood Risk Mitigation. These results indicate that project groups targeting these four categories of benefit will provide the greatest level of overall benefit to the region and to the general public. However, other impact categories are still important and should not be ignored.

It is important to note that of the top four categories of importance, benefits were quantified in monetary terms for only the Stormwater Conservation category. Stormwater Conservation was the only impact quantified in the Task 5 report, while the other three categories were only assessed qualitatively. Since three of the four most important impact categories indicated in the survey of STAC members are not quantified in the Task 5 report, the trade-off analysis provides important information in understanding the full benefits (both quantifiable and non-quantifiable) of the concepts.

Using three different methods of scoring for the trade-off analysis, groups of impact categories were used to develop a set of final concept scores. The three methods used a weighted average based upon a combination of the different benefits:

1. Stormwater Conservation, Capital Cost, Operations & Maintenance (O&M) Cost

2. Stormwater Conservation, Water Quality Impact, Climate Adaptation, Flood Risk Mitigation, Capital Cost, O&M Cost

3. Stormwater Conservation, Water Quality Impact, Climate Adaptation, Flood Risk Mitigation, Capital Cost, O&M Cost, Pollutant & Environmental Impact, Ecosystem Function, Environmental Justice Impacts, Energy Impact, Connectivity, Habitat, Environmental Compliance & Regulatory Permitting, Recreation, Financial Impact

The three sets of final scores are shown in Table ES-3. The different scoring methodologies were used to highlight which concepts may be potentially better in terms of specific criteria, and to show the scores' sensitivity to different combinations of benefits. From the analysis, the highest score for the first, second, and third scoring methods are 79, 81, and 71, respectively. These scores vary due to the different combinations of impact measures included in each scoring method.

As a note, a maximum score of 100 would only occur for a concept with the best possible performance in every category and for which no trade-offs occur. However, as a perfect concept does not exist, none of the concepts received a score of 100, and the concept scores shown in Table ES-3 need to be compared to each other on a relative basis. Rankings of the top five concepts for the three scoring methods are shown in Table ES-4.

Table ES-3. Weighted Final Scores of Concepts

Concept	Final Weighted Scores of Concepts		
	Score Including Stormwater Conservation and Cost Categories	Score Including Top 4 Impact Categories and Cost Categories	Score Including All Impact Categories
Local Solutions			
Local Stormwater Capture	47	51	52
Low Impact Development	49	59	54
Complete Streets	44	50	51
Regional Solutions			
Regional Stormwater Capture	53	61	48
Stormwater Conveyance Systems	43	35	44
Alternative Capture	47	38	40
Storage Solutions			
LACFCD Dams	74	57	41
USACE Dams	NA	NA	NA
Debris Basins	46	37	40
Management Solutions			
Stormwater Policies	52	54	52
Green Infrastructure Programs	51	60	50
Regional Impact Programs	25	47	48

Table ES-4. Concept Rankings Including Various Impact Categories

Rank	Including Stormwater Conservation and Cost Categories	Including Top 4 Impact Categories and Cost Categories	Including All Impact Categories
1st	LACFCD Dams	Regional Stormwater Capture	Low Impact Development
2nd	Regional Stormwater Capture	Green Infrastructure Programs	Local Stormwater Capture, Stormwater Policies (tied)
3rd	Stormwater Policies	Low Impact Development	-
4th	Green Infrastructure Programs	LACFCD Dams	Complete Streets
5th	Low Impact Development	Stormwater Policies	Green Infrastructure Programs

When considering all impact categories, the trade-off analysis indicates that Low Impact Development, Local Stormwater Capture, Stormwater Policies, Complete Streets, 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 any number of combinations of impact categories depending on the goals of different individuals, agencies, or groups.

The results presented in Tables ES-3 and ES-4 demonstrate how different combinations of impact categories can be analyzed to reflect different project priorities and result in different project rankings. In addition, measurement of changes in resource values and activities supported by those resources in this analysis is very qualitative.

It should be noted that a number of concepts with high scores also had much higher costs. However, if the qualitative benefits are targeted as the primary measures of interest, then using only the quantified economic benefits and costs as the measure of effects would lead to an incorrect conclusion. In other words, if a concept's multi-benefit aspect is the most important goal for considering a set of concepts, but only the quantified benefits and costs are used for justification, then this side-steps the goal of multi-benefit assessment and undermines the economic trade-off analysis. This is an important distinction between an analysis that only considers financial effects and an analysis that considers economic, environmental, and social effects.

Additionally, the final results of the economic analysis should not be used in isolation to evaluate and compare the project groups because of the large number of important benefit categories that could not be quantified. The results of the economic analysis combined with the trade-off analysis can be used as a baseline evaluation of concepts based on information provided by the Task 5 report. The results of the trade-off analysis can be adjusted to evaluate modified concepts/alternatives and to incorporate more detailed site specific estimates of resource impacts and values.

Through the trade-off assessment, this analysis evaluated a large number of potential concepts. By necessity, the level of detail that could be explored was very general. Given this level of analysis, the evaluation is essentially a screening analysis which can be used to identify the most promising concepts. It is critical to understand that an economic analysis and a broader trade-off analysis both require inputs from other disciplines to recognize and measure the impacts on resources and activities attributable to a concept and to value those impacts. If subsequent analyses are completed by other entities to better measure these impacts or to adjust the various weight of the impact categories, new scores for those resources could be calculated and used to re-rank the alternatives in future assessments.

1.0 Introduction

The Los Angeles Basin 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 highlights potential opportunities for modifications and changes to the existing regional stormwater capture system as well as opportunities to develop new facilities and practices, which could help to resolve future water supply and flood risk issues. *Task 6 – Trade-Off Analysis & Opportunities* provides a comparison of the various effects associated with the concepts identified in the *Task 5 – Infrastructure & Operations Concepts* report, and includes additional economic, financial, environmental, and social impact measures. Some effects are quantified and monetized, others are quantified but cannot be monetized, and some effects can only be evaluated qualitatively. The trade-off analysis uses multi-criteria evaluation techniques to compare the wide variety of effects and evaluates the quantifiable benefits and costs of the different stormwater concepts.

2.0 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 between LACFCD and several major water agencies were the driving force for creating a collaborative 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 and organizations to participate in a collaborative process to plan for future local water supply conditions and examine potential enhancement of existing facilities or develop new facilities to benefit the region.

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 existing dams and reservoirs and overlies several large groundwater basins. The Study Area includes more than 9 million people, and covers approximately 2,040 square miles. Los Angeles County accounts for the largest amount of water demand of any urbanized county in California.

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 resources available to meet potential future demand, and *Task 5 – Infrastructure & Operations Concepts,* which developed structural and nonstructural concepts to manage stormwater under future conditions. If the quantity demanded for water exceeds the quantity supplied, then the price of water will increase to reflect increased scarcity compared to a situation with no shortage. The Task 2 report addresses the supply and demand question, while the Task 5 report identifies resources that will be affected by the adaptive concepts. Some of these resources can be quantified while others cannot, and some resources can be monetized while others cannot. The benefits associated with a concept are derived from the change in the quantity or quality of a resource that can be attributed to the concept, such as the number of acre-feet of water conserved as a result of an alternative. The Task 5 report addresses the benefit categories generated by the concepts and provides quantitative or qualitative estimates of the resource impacts.

An economic analysis estimates the benefits and costs generated by a project in monetary terms and compares these two values. Benefits are derived by applying a representative resource value to the impacts provided in the Task 5 report, and costs are derived from the construction, land, and operation and maintenance costs estimated in the Task 5 report. If the estimated benefits exceed costs, then the project is said to be economically justified. Economic justification means that society is better off, in economic terms, with the project than without the project. If more than one project is under consideration and all of the potential projects are economically justified and feasible from an engineering standpoint, then the project with the greatest net benefit (total benefits minus total costs) would be the best economic choice.

An economic analysis is distinctly different than a financial analysis. As discussed above, an economic analysis is based on the benefits and costs generated by a project to whomever they may accrue and is therefore from a national perspective. The benefits and costs do not necessarily require an actual monetary exchange. For example, those benefiting from environmental improvements are not required to pay the costs needed to generate the environmental benefit. In contrast, a financial analysis is based on cash flows and is an evaluation of who actually pays the cost of a project. The financial cost may be imposed on federal, state, or local government agencies or on businesses and individuals. An economic analysis is not affected by who pays, while the source of payment is important in a financial analysis.

A trade-off analysis can include a broader range of impacts than an economic analysis because the effects do not need to be translated into monetary terms in order to compare the impacts of alternatives. The trade-off analysis estimates the impacts that projects under consideration would have on various resources and activities, provides a relative comparison of alternatives for each impact, and evaluates the strengths and weaknesses of each alternative and identifies which projects are best at providing specific types of benefits. The trade-off analysis results can be combined with information on the importance of different benefit categories to determine which alternative best satisfies the needs of the benefited region. The 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.

It is important to understand that the economic and trade-off analyses both require inputs from other disciplines to understand and measure the resource and activity impacts attributable to a project or action and to value these impacts. For example, if there is the potential for water supply benefits due to a supply shortage, then a project will generate water supply benefits only if the project provides increased water supplies relative to conditions if no project is in place. Engineering, hydrological, and water quality data and analyses are needed to estimate the quantity and quality of water supplies provided. The magnitude of benefits depends on the quantity, quality, and timing of increased water supplies. Similarly, if there are potential flood reduction benefits, then the risk of flooding and the value of potential flood damages with and without a project would be needed in order to estimate flood control benefits.

3.0 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 among concepts. 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.

Basin studies typically rely on existing data and information to evaluate impacts and assess trade-offs. As a result, some areas of measurement and evaluation in this trade-off analysis are fairly general and, as a result, uncertainties exist. These uncertainties are identified in the trade-off analysis.

3.1 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 the outputs identified and computed in Task 5.

The second step is to place values on the quantifiable outputs and costs. This step is the economic benefit 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. Another type of analysis that is similar to an economic analysis is a financial analysis, which evaluates the ability of project beneficiaries to pay the costs associated with a project or action and the impact on local government and businesses.

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

4.0 Benefits Identified in Task 5

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 ES-2 of the Task 5 report and are presented below in Tables 1 and 2. The qualitative impacts were designated with symbols indicating low or no benefits, moderate benefits, or high benefits in the Task 5 report and are scored relative to each concept. It should be noted that, in addition to miles of recreation trails, some recreational qualitative impacts were identified in Table ES-2 of the Task 5 report, but the emphasis in this Task 6 analysis is on miles of trails. The impacts identified in the Task 5 report are an important part of the assessment of potential concept benefits.

Table 1. Quantified Benefits in Task 5 – Infrastructure & Operations Concepts

Project Group	Stormwater Conserved/Storage Capacity (AFY)		Recreation (miles of trail)	Habitat (acres)	Right of Way Acquired (acres)
	Low	High			
Local Solutions					
Local Stormwater Capture	23,900	39,200	204	266	2,655
Low Impact Development	76,300	111,300	0	672	0
Complete Streets	25,800	36,900	614	725	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	153,000	225,800	768	1,798	0
Green Infrastructure Programs	99,700	145,300	0	857	0
Regional Impact Programs	92,000	195,400	527	5,200	7,600

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

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

5.0 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 additional supplies required to bridge the gap between supply and demand in the future as identified in the *Task 2 – Water Supply & Water Demand Projections* report during drought periods. Reliability improvements 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.

5.1 The 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 (WTP) 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 WTP.

1. **Stated Preference Approach –** The use of survey data to directly estimate benefits based on the stated WTP 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 individuals through the prices paid for and quantities purchased of a good or service. Market price and quantity combinations can be used to estimate WTP functions from which benefits can be estimated.
3. **Benefits Transfer Approach –** The use of results from previously completed studies to estimate benefits for a concept 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 Approach –** 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 WTP 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 WTP.

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 WTP is derived. However, this is also the primary disadvantage of the approach. Cost-based approaches do not measure WTP, 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 WTP.

It should be noted that another type of analysis that is frequently used to compare alternatives is cost effectiveness analysis, which is based on the total cost of obtaining a water supply. 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 alternatives and the one with the lowest cost per unit 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 because benefits are not actually measured.

An example of a cost-based approach application is the avoided cost of purchasing Metropolitan Water District of Southern California (MWD) water and the value of financial subsidies provided by MWD for development of water supplies used in the Los Angeles Department of Water and Power (LADWP) Stormwater Capture Master Plan (LADWP, 2015). The logic of cost-based approaches is that avoided costs are equivalent to benefits, or total value of water, because that amount would need to be spent in order to acquire supplies in the absence of a project. However, that is not exactly the question that needs to be addressed when estimating benefits. Benefits are based on WTP, and expenditures for water supplies are justified as long as they are less than or equal to WTP. As an example, suppose there is an isolated area that has no additional surface or ground water supplies to meet demand and the only alternative is to haul water at a cost of $20,000 per acre-foot. The avoided cost of implementing a re-use program would be estimated to be $20,000 per acre-foot but it may be that water users would not be willing to pay an average of $20,000 per acre-foot for water. So using the avoided cost approach in this case would overstate benefits, perhaps by a very large margin. It is also possible to create a scenario where avoided cost understates benefits. The main point is that cost based approaches are not necessarily a theoretically correct measure of benefit, but it is an important financial consideration.

The relevant measure of benefit used to evaluate the concepts is the WTP of water users for increased water supply reliability, where WTP represents the total benefit of the water supply. It would be incorrect to add the cost of obtaining a water supply to WTP because the sum of the two values would exceed WTP and would overstate benefits. The correct measure of net benefit of a concept is the WTP for a water supply minus the cost of obtaining the supply.

Given resource and time constraints, as well as limited input data available, the benefits transfer approach was selected for use in this analysis. There are three 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 level on a per household basis. Therefore, the values need to be converted into wholesale level values.

2. 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.

3. 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 previous sites from which benefits are estimated (the existing studies) are similar enough to the new concept areas for which benefit estimates are needed (this current analysis). Therefore, the existing estimated benefits are considered representative values and can be used in this analysis. The benefits transfer approach is considered an acceptable approach for measuring WTP as part of an analysis presenting 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.

5.1.1 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, all of which are based on the stated preference approach, are discussed below.

Barakat and Chamberlin Study

A study prepared by Barakat and Chamberlin (1994) estimated the mean monthly 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 WTP 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 WTP 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 WTP 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 WTP 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) compared 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 WTP to avoid various shortage percentages at different intervals. The range of estimated WTP was $83 to $258 annually per household in 1987 dollars. The estimated WTP 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. 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)

5.1.2 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 for a screening type of analysis. 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. Derivation of the Wholesale Portion of Water Supply Costs as a Percentage of Total Cost

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.

5.1.3 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 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 indicated in the conclusions section of the Task 2 report for 2095 ranged from an upper bound of 138 gallons per capita per day (gpcd) to a lower bound of 64 gpcd. The 138 gpcd and 100 gpcd estimates represent usage values based on "high" and "medium" demand scenarios while the 64 gpcd estimate is the "low" demand scenario. This economic analysis is based on a 50- year period, which extends to the mid-point of the future time periods included in the Task 2 analysis. Therefore, the Task 2 water use estimates cannot be matched exactly with the time period used in this analysis. For this analysis, the range of use rates are based on the range for "medium" and "high" future water use of 100 gpcd to 138 gpcd, respectively. 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.

5.1.4 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
Griffin & 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 retail level 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 Griffin and Mejelde study (2000) is based on Texas data and the Barakat and Chamberlin study results showed some inconsistency in the WTP 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 WTP to avoid a 1 in 10 year occurrence of a 10% shortage. The Koss and Khawaja study lower bound estimate of WTP 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. It should be noted that the best estimate of benefits presented in Table 9 is based on an annual water supply benefit of $73 per household and a mid-point household water use value of 119 gallons per capita per day, which translates into 0.401 acre-feet per household per year. As indicated in the discussion of the Koss and Khawaja study (2001), the $73 value represents the WTP to avoid a 1 in 10 year occurrence of a 10% shortage.

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. 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	51,366	84,248	70,886	116,264	$2,619,700	$19,299,800	$6,118,500
Low Impact Development	163,985	239,208	226,300	330,107	$8,363,300	$54,797,800	$18,034,400
Complete Streets	55,450	79,306	76,521	109,443	$2,827,900	$18,167,500	$6,018,600
Regional Solutions							
Regional Stormwater Capture	56,095	128,738	77,411	177,659	$2,860,800	$29,491,600	$8,532,000
Stormwater Conveyance Systems	17,194	21,492	23,727	29,659	$876,900	$4,923,400	$1,710,100
Alternative Capture	8,167	14,830	11,271	20,465	$416,500	$3,397,200	$1,045,100
Storage Solutions							
LACFCD Dams	123,365	567,609	170,244	783,300	$6,291,600	$130,027,800	$33,093,300
USACE Dams	8,167	25,361	11,271	34,998	$416,500	$5,809,600	$1,575,500
Debris Basins	193	494	267	682	$9,900	$113,200	$32,000
Management Solutions							
Stormwater Policies	328,830	485,294	453,786	669,705	$16,770,400	$111,171,100	$36,446,600
Green Infrastructure Programs	214,277	312,281	295,702	430,948	$10,928,100	$71,537,400	$23,550,700
Regional Impact Programs	197,728	419,957	272,865	579,541	$10,084,100	$96,203,800	$28,370,300

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	$66	$485	$154
Low Impact Development	$210	$1,377	$453
Complete Streets	$71	$457	$151
Regional Solutions			
Regional Stormwater Capture	$72	$741	$214
Stormwater Conveyance Systems	$22	$124	$43
Alternative Capture	$10	$85	$26
Storage Solutions			
LACFCD Dams	$158	$3,268	$832
USACE Dams	$10	$146	$40
Debris Basins	$0.2	$3	$1
Management Solutions			
Stormwater Policies	$421	$2,794	$916
Green Infrastructure Programs	$275	$1,798	$592
Regional Impact Programs	$253	$2,418	$713

5.2 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 (USACE) 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 to the USACE study indicated an average trail use per mile of 22,490 users annually. This use per mile value was applied in the USACE study to conditions with or without 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 urban recreation represented by additional trails, the lower bound estimate of the confidence interval is used in this analysis and is considered the best estimate of recreational benefits. The recreation benefit estimate is $5.47 per visit indexed to 2014 dollars. Recreation benefits for each of the concepts are presented in Table 10.

Table 10. Recreation Benefits Associated with Additional Trails

Concept	Miles of Trail	Annual Increase in Use at 22,480 Visits per Mile	Annual Total Recreational Value at $5.47 per Visit	Estimated Present Value of Recreational Benefits (millions)
Local Solutions				
Local Stormwater Capture	204	4,585,409	$25,082,200	$630
Low Impact Development	0	0	$0	$0
Complete Streets	614	13,802,720	$75,500,900	$1,897
Regional Solutions				
Regional Stormwater Capture	12	268,227	$1,467,200	$37
Stormwater Conveyance Systems	3	76,713	$419,600	$11
Alternative Capture	2	50,696	$277,300	$7.0
Storage Solutions				
LACFCD Dams	0	0	$0	$0
USACE Dams	0	0	$0	$0
Debris Basins	1	13,922	$76,200	$2
Management Solutions				
Stormwater Policies	768	17,264,640	$94,437,600	$ 2,373
Green Infrastructure Programs	0	0	0	$0
Regional Impact Programs	527	11,846,960	$64,802,900	$1,629

5.3 Potential Habitat Benefits, Environmental Values, and Ecosystem Service Values

5.3.1 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).

Carbon is found in all living organisms and is the major building block for life on Earth. Carbon exists in many forms, predominately as plant biomass, soil organic matter, dissolved in seawater, and as carbon dioxide (CO_2) in the atmosphere. Most scientists believe that there is a direct relationship between increased levels of CO_2 in the atmosphere and rising global temperatures. Human civilization developed in an atmosphere of about 275 parts per million (ppm) of CO_2. Global CO_2 recently surpassed 400 ppm and 2 ppm is being added annually. The 2015 United Nations Conference on Climate Change COP 21 agreement demonstrated widespread acknowledgement that a sharp reduction in emissions and a parallel effort to sequester atmospheric CO_2 are both necessary to reduce rising global temperatures and avoid long-term climate impacts.

Carbon sequestration represents the potential for long-term storage of carbon in oceans, soils, vegetation, and geologic formations. One proposed method to help reduce atmospheric CO_2 is to increase the sequestration of carbon in soils by restoring soil health. Maintaining and increasing soil organic matter (SOM) adds to soil fertility, water retention, erosion control, and crop production. Increasing the acreage of vegetated SOM throughout Greater Los Angeles County could then provide a cost-effective mechanism for both water conservation and carbon sequestration.

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 for a screening type of analysis 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 WTP are presented in Table 11 (Executive Office of the President, 2011). The range of potential ecosystem benefits shown in Table 11 is extremely 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 refuges 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 WTP to avoid climate change damages.

5.3.2 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 per acre minimum value for rivers and lakes from the Executive Office of the President (2011) analysis, and the estimated habitat acreage associated with each concept. The minimum value from the Executive Office of the President analysis was used as a conservative estimate of benefits given the unknown extent to which the concepts would generate habitat benefits. Subsequent analyses of the concepts may be able to better define the extent to which habitat benefits are generated and the habitat benefits could be made more precise. 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 estimated annual habitat related benefits are shown in Table 13 and the present value of habitat benefits over the 50-year planning period are shown in Table 14.

Table 13. Annual 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	672	0	672	$94,800	$483,200
Complete streets	725	0	725	$102,200	$521,300
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	1,798	0	1,798	$253,500	$1,292,800
Green Infrastructure Programs	857	0	857	$120,800	$616,200
Regional Impact Programs	5,200	2,470	7,670	$1,081,500	$5,514,700

Table 14. Present Value of Benefits Associated with Habitat Acreage over the 50-year Planning Period

Concept	Present Value of Habitat Benefits at $141/Acre	Present Value of Habitat Benefits at $719/Acre	Mid-Point of Lower and Upper Bound Present Value Benefits/Acre
Local Solutions			
Local Stormwater Capture	$942,500	$4,806,200	$2,874,400
Low Impact Development	$2,381,100	$12,142,000	$7,261,600
Complete streets	$2,568,900	$13,099,700	$7,834,300
Regional Solutions			
Regional Stormwater Capture	$148,800	$758,900	$453,800
Stormwater Conveyance Systems	$28,300	$144,500	$86,400
Alternative Capture	$7,100	$36,100	$21,600
Storage Solutions			
LACFCD Dams	$0	$0	$0
USACE Dams	$0	$0	$0
Debris Basins	$0	$0	$0
Management Solutions			
Stormwater Policies	$6,370,900	$32,487,200	$19,429,100
Green Infrastructure Programs	$3,036,600	$15,484,700	$9,260,700
Regional Impact Programs	$27,177,400	$138,585,600	$82,881,500

6.0 Quantified Economic Benefits and Costs

As described in detail above, economic benefits were quantified for water supply reliability, recreation associated with trail use, and potential environmental benefits associated with habitat and right-of way acreage using estimates of changes in resources associated with each concept quantified in the Task 5 report. The Task 5 report also provided the capital, land, and annual operation and maintenance costs for each concept. For this analysis all costs are estimated as a present value, where annual costs are present valued using the current water project planning rate of 3.125 percent. The present value of quantified benefits and costs are presented in Table 15 and Table 16. Costs are not presented for the USACE Dams concept because cost estimates were not provided for capital, land, and operation and maintenance costs in the Task 5 report for this concept. As a result, comparable costs could not be calculated for USACE Dams. The information presented in Tables 15 and 16 can be used by decision makers to evaluate the relative magnitudes of quantified benefits and costs associated with each concept.

Table 15. Best Estimate of Quantified 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	$787	$8,410
Low Impact Development	$460	$21,055
Complete Streets	$2,056	$12,253
Regional Solutions		
Regional Stormwater Capture	$251	$1,320
Stormwater Conveyance Systems	$54	$10,346
Alternative Capture	$33	$227
Storage Solutions		
LACFCD Dams	$832	$668
USACE Dams	$40	N/A
Debris Basins	$3	$74
Management Solutions		
Stormwater Policies	$3,309	$43,362
Green Infrastructure Programs	$601	$26,681
Regional Impact Programs	$2,424	$97,211

It is important to note that benefits can be quantified for only a subset of the total potential beneficial effects associated with the infrastructure and operations concepts identified in the Task 5 report. There are many potential benefits associated with environmental and social improvements, flood risk mitigation, environmental justice, and other effects that are potentially very large but cannot be evaluated quantitatively for a screening type of analysis. These unquantified benefits may be larger than quantified benefits in some cases and smaller in other cases. The intent of the qualitative assessment is to provide an indication of the potential relative magnitude of unquantified benefits.

Table 16. 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	$66	$485	$630	$1	$5	$697	$1,120	$4,414	$3,996
Low Impact Development	$210	$1,377	$0	$2	$12	$212	$1,389	$9,696	$11,359
Complete Streets	$71	$457	$0	$3	$13	$74	$470	$5,970	$6,283
Regional Solutions									
Regional Stormwater Capture	$72	$741	$37	$0	$1	$109	$779	$993	$327
Stormwater Conveyance Systems	$22	$124	$11	$0	$0	$33	$135	$7,154	$3,192
Alternative Capture	$10	$85	$7	$0	$0	$17	$92	$152	$75
Storage Solutions									
LACFCD Dams	$158	$3,268	$0	$0	$0	$158	$3,268	$252	$426
USACE Dams	$10	$146	$0	$0	$0	$10	$146	NA	NA
Debris Basins	$0	$3	$2	$0	$0	$2	$5	$41	$33
Management Solutions									
Stormwater Policies	$421	$2,794	$2,373	$6	$32	$2,800	$5,199	$20,443	$22,919
Green Infrastructure Programs	$275	$1,798	$0	$3	$15	$278	$1,813	$12,508	$14,173
Regional Impact Programs	$253	$2,418	$1,629	$27	$139	$1,909	$4,186	$70,699	$26,512

7.0 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 even 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.

7.1 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 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 Acquired, measured in new acreage
- 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 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 17.

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 and 10 for each individual survey. For example, if the highest score from an individual survey for a measure was an 8, this score would represent the highest possible score for that individual survey and was the basis for normalizing all category scores. If a score of 4 was given for another category on the same survey, the normalized score would become (4÷8)x10 or a 5.00. In this way the maximum normalized score for a category would be a 10.0 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 18. 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 17. 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 & 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 18. Normalized Ranking of Importance for Measures Included in STAC Survey

Rank	Measure	Average of Normalized Individual Importance Scores	Normalized Average Importance Score
1	Stormwater Conservation	9.62	10.00
2	Water Quality Impact	8.53	8.86
3	Climate Adaptation	7.69	7.99
4	Flood Risk Mitigation	7.68	7.98
5	Pollutant & Environmental Impact	7.37	7.66
6	Operations & Maintenance Cost	6.88	7.15
7	Ecosystem Function	6.67	6.93
8	Environmental Justice Impacts	6.56	6.82
9	Health & Well-Being Impacts	6.50	6.76
10	Energy Impact	6.48	6.74
11	Capital Cost	6.42	6.67
12	Connectivity	6.27	6.52
13	Habitat	6.07	6.31
14	Endangered Species	5.69	5.92
15	Environmental Compliance & Regulatory Permitting	5.67	5.90
16	Regional Economic Impact	5.59	5.81
17	Education	5.34	5.55
18	Recreation	5.25	5.46
19	Financial Impact	5.00	5.20

It is interesting to note that the categories related to costs and financial effects were ranked 6th, 11th, and 19th out of 19 categories. The most important of the cost related categories was operations and maintenance costs, while capital cost was ranked in the bottom half of importance and financial effects was ranked least important. To some extent, the rankings indicate a "cost is no object" approach, where the first inclination is to try and obtain an outcome that provides everything we want which is then later modified to incorporate budget constraints.

A correlation analysis was completed for the 19 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 for 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 19 and a description of correlated measures is presented in Table 20. For each of the discarded measures, there are at least two correlated measures that are included as a retained measure.

Table 19. 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 & 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 & 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 & 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 and Recreation
Education	Discard/Combine	Correlated with 6 variables
Health & Well Being	Discard/Combine	Correlated with 6 variables

Table 20. Description of Measures Correlated to Discarded Measures

Discarded Measure	Correlated Measures
Endangered Species	Habitat, Pollutant & 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 & Environmental Impact, Energy Impact, Endangered Species, Environmental Justice
Health & 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 21. 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 21. Measures and Weights used in Trade-Off Analysis in Descending Order of Importance

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 & Regulatory Permitting	5.90
Recreation	5.46
Financial Impact	5.20

7.2 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 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.

7.2.1 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 22.

Table 22. Pollution Burdens and Population Characteristics Included in the CalEnviroScreen Score

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

This trade-off analysis should be considered a screening level analysis of concepts that can be used to help identify alternatives that could be evaluated for feasibility in the future. 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

Information from the CalEnviroScreen tool is used to establish representative values for each concept for four social and environmental impact categories: pollutant and environmental impact, ecosystem function, connectivity, and environmental justice.

Pollutant and Environmental Impact

The pollution burden score discussed above is an indicator of the potential for exposures and environmental effects in an area and is therefore a reasonable proxy for pollutant and environmental impacts. It would be expected that concepts that potentially improve environmental conditions would have a positive impact if there is currently the potential for exposures and environmental effects. Therefore, relatively high pollution burden rankings would translate into beneficial pollutant and environmental impacts.

Ecosystem Function

Ecosystem function was defined in the STAC survey as changes in the interactions between organisms and the physical environment, such as nutrient cycling, soil development, and water budgeting. Although there is no specific category included in the CalEnviroScreen tool for ecosystem function, the average of impaired water and groundwater threat scores were used as an indicator of ecosystem function to represent groundwater interaction and potential water impairment.

Connectivity

Connectivity was defined in the STAC survey as the change in the degree to which the landscape facilitates movement of people, wildlife movement, and other ecological flows. Since connectivity can be thought of in terms of overall ecological health, the overall Cal Environ Score was used as an indicator of connectivity

Environmental Justice

The poverty percentages combined with the percentage of non-white population were used as an indicator of areas with potential environmental justice concerns. When evaluating environmental justice issues associated with a structural project, adverse environmental justice impacts can occur as a result of the negative effects of building a structure near minority or low income populations. The three structural solutions included in the concepts under consideration in this analysis are located in areas that do not have a disproportionate percentage of minority and low income populations. The non-structural concepts are located in areas that do have high percentages of minorities and low income populations. However, the non-structural concepts would have beneficial environmental impacts and would therefore be expected to provide environmental justice benefits which would essentially help mitigate existing environmental justice concerns. In order to account for these positive environmental justice impacts, the qualitative benefits identified in the Task 5 report for aesthetics and heat island mitigation are used to represent environmental justice benefits. It is expected that improved aesthetics and reduced heat island effects would be closely correlated with improved general environmental conditions. The average benefit for these two categories of qualitative benefits is used to represent positive environmental justice effects.

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 23. The tract scores used to calculate representative concept values for impaired water impacts, groundwater threats, pollution burden, and the overall Cal Environ Score are presented in Table A-1 of Appendix A. Tract scores for poverty, population characteristics, and whether or not the tract has a disadvantaged designation are also presented in Table A-1. The tracts included for each concept are also described in Appendix A.

7.2.2 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 24 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 25.The scores displayed in Table 24 for flood risk, water quality, climate adaptation, and environmental justice were taken directly from the qualitative description of benefits in the Task 5 report and reproduced in Table 2 of this report. Identification of low/no benefits is given a 0 score, moderate benefits a 50 score, and high benefits a 100 score. Environmental justice was an average of aesthetics and heat island mitigation, so possible scores were 0, 25, 50, 75, or 100 for environmental justice. The energy measure is based on the Task 5 reported energy consumption for each concept in kilowatt hours per year. The Task 5 report indicated energy consumption for only the Regional Stormwater Capture and Alternative Capture concepts. Financial impacts were based on the present value of all costs over the 50-year period of analysis. The relative financial impact of each concept is a function of the costs that need to be repaid for each potential project. Potential cost-sharing arrangements and methods of financing the various types of projects would affect the magnitude of financial impacts, but these variables are unknown. Therefore, the relative total cost is used as a measure of financial impact. The score for stormwater is based on the mid-point of the range of stormwater conserved/storage capacity estimates. The environmental compliance score was based on the description of implementation challenges in Appendix B: Project Group Fact Sheets of the Task 5 report.

Table 23. Population and Environmental Characteristics from CalEnviroScreen 2.0

Concept	Population	Pollution Burden	Population Characteristics	% White	% Latino	% Asian	% African American	Cal Enviro Score	Impaired Water	Groundwater 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 24. 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	17	94	85	5	27	100	50	91	100	100	100	50	100	100	100
Low Impact Development	50	86	57	13	0	100	50	78	100	100	100	100	100	100	100
Complete Streets	17	92	76	14	80	100	50	87	100	100	100	50	100	100	50
Regional Stormwater Capture	23	99	99	1	2	67	50	99	50	100	91	100	63	92	75
Stormwater Conveyance	5	90	88	0	0	100	50	89	100	50	97	0	95	98	100
Alternative Capture	3	100	100	0	0	0	0	100	100	100	97	0	95	98	75
LACFCD Dams	85	100	98	0	0	100	50	99	0	0	71	100	73	60	25
USACE Dam	4	NA	NA	0	0	100	50	NA	0	0	50	50	45	50	50
Debris Basins	0	100	100	0	0	100	0	100	100	50	97	50	95	97	0
Stormwater Policies	100	71	14	35	100	100	50	55	100	100	90	50	80	87	50
Green Infrastructure Programs	65	82	47	16	0	100	50	73	50	100	90	100	80	87	100
Regional Impact Programs	76	0	0	100	69	100	50	0	50	100	91	100	63	92	100

Table 25. 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	17	63	61	3	15	67	40	47	59	89	77	40	69	65	68
Low Impact Development	50	57	41	8	0	67	40	41	59	89	77	80	69	65	68
Complete Streets	17	61	54	9	44	67	40	45	59	89	77	40	69	65	34
Regional Stormwater Capture	23	66	71	1	1	45	40	52	30	89	70	80	44	60	51
Stormwater Conveyance	5	60	63	0	0	67	40	46	59	44	74	0	66	64	68
Alternative Capture	3	67	72	0	0	0	0	52	59	89	74	0	66	64	51
LACFCD Dams	85	67	70	0	0	67	40	51	0	0	54	80	51	39	17
USACE Dam	4	NA	NA	0	0	67	40	NA	0	0	38	40	31	33	34
Debris Basins	0	67	72	0	0	67	0	52	59	44	74	40	66	63	0
Stormwater Policies	100	47	10	22	55	67	40	29	59	89	69	40	55	57	34
Green Infrastructure Programs	65	55	34	10	0	67	40	38	30	89	69	80	55	57	68
Regional Impact Programs	76	0	0	63	38	67	40	0	30	89	70	80	44	60	68

Finally, the weighted average scores from Table 25 can be averaged to compare each concept considering the important impact measures identified by the STAC. Different categories can be considered when comparing concepts, depending on the impacts that are considered to be most important.

For the final scores, the highest possible score any concept could have received is a 100. However, because there were no perfect concepts, or concepts with no trade-offs and a perfect 10 in all of scoring categories, the scores are lower than 100. Because of this, these concept scores should be compared to each other on a relative scale.

The STAC survey results indicated stormwater conservation was the most important category of impact, followed by water quality, climate adaptation, and flood risk mitigation. These results indicate that project groups targeting these four categories of benefit could provide the greatest level of overall benefit to the general public. In addition, project cost need to be considered in any evaluation of projects. In order to account for the importance of the four top benefit categories of impacts, concept scores for two additional groups of impact categories are calculated. The first includes costs as well as stormwater conservation. The second includes costs as well as stormwater conservation, water quality, climate adaptation, and flood risk mitigation. The concept trade-off scores for the 3 different groups of impact categories are shown in Table 26. The maximum average score considering only stormwater conservation and costs is a 79 and the maximum average score considering the top four impact categories and costs is an 81. The maximum average scores vary due to the different categories and their weights included in each of the combinations. Rankings of the top 5 concepts for the three impact groups are shown in Table 27.

Table 26. Average Trade-Off Weighted Scores of Concepts Including Selected Impact Categories

Concept	Final Weighted Scores of Concepts		
	Average including Stormwater Conservation and Cost Categories (Maximum of 79)	Average Including Top Four Impact Categories and Cost Categories (Maximum of 81)	Average Including all Impact Categories (Maximum of 71)
Local Solutions			
Local Stormwater Capture	47	51	52
Low Impact Development	49	59	54
Complete Streets	44	50	51
Regional Solutions			
Regional Stormwater Capture	53	61	48
Stormwater Conveyance Systems	43	35	44
Alternative Capture	47	38	40
Storage Solutions			
LACFCD Dams	74	57	41
USACE Dams	NA	NA	NA
Debris Basins	46	37	40
Management Solutions			
Stormwater Policies	52	54	52
Green Infrastructure Programs	51	60	50
Regional Impact Programs	25	47	48

Table 27. Concept Rankings Including Various Impact Categories

Rank	Including Stormwater Conservation and Cost Categories	Including Top 4 Impact Categories and Cost Categories	Including all Impact Categories
1st	LACFCD Dams	Regional Stormwater Capture	Low Impact Development
2nd	Regional Stormwater Capture	Green Infrastructure Programs	Local Stormwater Capture, Stormwater Policies (tied)
3rd	Stormwater Policies	Low Impact Development	-
4th	Green Infrastructure Programs	LACFCD Dams	Complete Streets
5th	Low Impact Development	Stormwater Policies	Green Infrastructure Programs

The groupings of categories and resulting rankings shown in Table 27 indicate which concepts are best at providing the most important category of benefit (stormwater conservation/storage) considering cost, which concepts are best at providing the four most important categories of benefits (stormwater conservation/storage, water quality, climate adaptation, and flood risk mitigation) considering cost, and which concepts are best considering all impact categories.

Considering only stormwater conservation/storage and costs, the LACFCD Dams concept is the highest ranked concept, followed by Regional Stormwater Capture and Stormwater policies. However, adding the more environmentally oriented measures that round out the top four most important categories of benefits (water quality and climate adaptation) along with flood risk mitigation drops the LACFCD Dams concept from number 1 down to 4th place, and considering all categories the LACFCD Dams concept drops down to 9th place. Local Solutions along with regional Stormwater Conveyance Systems and regional Alternative Capture appear to be much less effective at providing stormwater water supplies at a relatively low cost.

However, when the top four impacts and cost categories are considered, some of the Management Solutions and Local Solutions rise to the top of the rankings while LACFCD Dams drop towards the middle of the concepts considered. It must be recognized that these rankings are based on the levels of importance indicated by the STAC survey results and do not consider financial feasibility or the ability of project beneficiaries to pay for a project. Therefore, it is possible that relatively expensive projects such as Stormwater Policies and Green Infrastructure Programs rank high, but are not financially feasible at the level of implementation considered in this analysis.

8.0 Summary and Opportunities

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. It is important to note that benefits can be quantified for only a subset of the total potential beneficial effects associated with the infrastructure and operations concepts identified in the Task 5 report. There are many potential benefits associated with environmental and social improvements, flood risk mitigation, environmental justice, and other effects that are potentially very large, but cannot be evaluated quantitatively for a screening type of analysis such as this. These unquantified benefits may be larger than quantified benefits in some cases and smaller in other cases. The intent of the qualitative assessment is to provide an indication of the potential magnitude of unquantified benefits.

The results of the economic analysis indicate the LACFCD Dams concept is the only concept that generates quantified benefits that exceed costs. Stormwater Policies, Regional Impact Programs, and Local Stormwater Capture generate benefits that are of a higher or similar magnitude as the LACFCD Dams concept but at a much higher cost. The other concepts generate substantially lower benefits.

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. The primary source of information for resource impacts associated with each concept is the Task 5 report. However, additional information is obtained from the CalEnviroScreen tool to evaluate additional social, environmental, and environmental justice issues.

The trade-off analysis incorporated the information for quantitative and qualitative impacts for each concept group and the importance weights based on the STAC survey results to calculate a final score for each project group. All scores prior to weighting are measured relative to the highest scoring concept. This approach allows all quantitative and qualitative effects to be expressed as values that are comparable across the different effects where higher scores indicate higher combined benefits.

The STAC 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 and flood risk mitigation. These results indicate that project groups targeting these four categories will provide the greatest level of overall benefit to the region and to the general public. However, other impact categories are still important and should not be ignored.

It is important to note that of the top four categories of importance, benefits were quantified in monetary terms for only the stormwater conservation category. Stormwater conservation was the only impact quantified in the Task 5 report, while the other four categories were only assessed qualitatively. Since 3 of the 4 most important impact categories indicated in the survey of STAC members are not quantified in the Task 5 report, the trade-off analysis provides important information in understanding the full benefits (both quantitative and qualitative) of the concepts.

The trade-off analysis indicates Local Stormwater Capture, LACFCD Dams, Regional Impact Programs, Green Infrastructure Programs, and Low Impact Development 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 results presented in Tables 27 and 28 demonstrate how different combinations of impact categories can be analyzed to reflect different project priorities and result in different project rankings. In addition, measurement of changes in resource values and activities supported by those resources in this analysis is very qualitative.

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 results presented in Tables 27 and 28 demonstrate how different combinations of impact categories can be analyzed which reflect different project priorities and result in different project rankings. From this analysis, a number of opportunities with high stormwater conservation potential have been explored, most notably: LACFCD Dam, 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.

This analysis evaluated 12 different project groups, which is a very large number of potential concepts. By necessity, the level of detail is at the reconnaissance level. Given the level of analysis, this evaluation is essentially a screening analysis which can be used to identify the most promising concepts. It is critical to understand that an economic analysis and a broader trade-off analysis both require inputs from other disciplines to understand and measure the impacts on resources and activities attributable to a project or action and to value those impacts. If subsequent analyses are completed by other entities which provide a better measure of these impacts, new scores for those resources could be calculated and used to re-rank the alternatives. It is likely that these additional analyses would be completed for a subset of projects.

The final results of the economic analysis should not be used in isolation to evaluate and compare the project groups because of the large number of important benefit categories that could not be quantified. The results of the economic analysis combined with the trade-off analysis can be used as a baseline evaluation of concepts based on existing information provided by the Task 5 report. The results of the trade-off analysis can be adjusted to evaluate modified concepts/alternatives and to incorporate more detailed site specific estimates of resource impacts and values. One of the more notable contributions of this analysis to future project planning is the derivation of weights used to evaluate the relative importance of different impact categories based on a survey of STAC members. These weights can be applied to the current or revised estimates of impacts from a concept/alternative and used to rank alternatives.

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Appendix A
Sources of Information Used to Calculate Pollutant & Environmental Impact, Ecosystem Function, and Connectivity

Potential implementation areas were identified in the Task 5 report and those areas were matched as closely as possible to tracts in the CalEnviroScreen tool. Table A-1 indicates the tracts that were specifically used for the USACE Dam and the Regional Stormwater Capture concepts. The Regional Stormwater Capture scores were also applied to the Regional Impact Programs concept because they both affect similar areas. The tracts for the LACFCD Dams concept include tracts for Morris Dam, Pacoima Dam, Puddingstone Diversion, San Dimas Dam, San Gabriel Dam, Cogswell Dam, and Big Tujunga Dam. The tracts included for the Stormwater Conveyance concept included the tracts identified for Bell, Browns, Aliso, Bull, Tujunga, Burbank West, Verdugo, Arroyo Seco, Alhambra, Rubio, Eaton, Rio Hondo, Big Dalton, Walnut, and San Jose. The values for the Stormwater Conveyance concept were also applied to the Alternative Capture and Debris Basin concepts because they appear to impact similar area. Scores for Local Stormwater Capture, Low Impact Development, and Complete Streets were based on the average scores of the tracts included in Stormwater Conveyance and Regional Stormwater Capture to represent a wide region of effects. The average was used because these three concepts could be spread out over a large non-specific area. Finally, the Stormwater Policies and Green Infrastructure Programs concepts were based on the average scores of all the tracts. The average was used because these three concepts could be spread out over a large non-specific area in the region. Scores for all of the above concepts were based on average weighted scores of each tract, where the weight that was applied is the population of the individual tract relative to the population of all tracts applied to the concept.

Table A-1. Scores Used to Evaluate Pollutant and Environmental Impact, Ecosystem Function, and Connectivity in the Trade-off Analysis

Tract	Impaired Water	Groundwater Threat	Poverty	Cal Environ Score	Pollution Burden	Population Characteristics	Disadvantaged?
Bell							
6037134422	29	11	21	41 - 45%	37	45	No
6037134303	29	54	28	56 - 60%	71	41	No
6037135111	29	78	41	51 - 55%	76	30	No
6037134520	29	80	88	66 - 70%	65	64	No
6037134521	29	27	84	76 - 80%	54	85	No
6037134001	29	26	84	76 - 80%	63	78	No
6037134002	29	5	54	56 - 60%	52	51	No
Browns							
6037134201	29	52	54	66 - 70%	69	54	No
6037134104	29	16	57	56 - 60%	43	66	No
6037113422	0	39	34	61 - 65%	57	55	No
6037113234	0	52	74	76 - 80%	67	72	Yes
6037134710	29	0	77	61 - 65%	49	64	No
Aliso							
6037132501	42	36	58	66 - 70%	45	80	No
6037131020	42	70	54	56 - 60%	59	53	No
6037131702	42	36	52	56 - 60%	48	59	No
6037131600	42	52	59	56 - 60%	50	56	No
6037131010	42	41	73	61 - 65%	55	59	No
Bull							
6037132102	77	60	58	86 - 90%	88	72	No
6037980008	77	5	99	91 - 95%	78	95	Yes
6037132101	77	10	51	81 - 85%	92	57	Yes
6037127604	0	0	79	81 - 85%	71	80	Yes
6037127603	0	0	80	66 - 70%	70	91	No
Tujunga							
6037125200	64	63	68	71 - 75%	84	56	No
6037123902	0	18	65	46 - 50%	72	27	No
6037124102	0	50	58	61 - 65%	78	46	No
6037123901	0	80	64	71 - 75%	83	56	No
6037124104	0	39	82	86 - 90%	73	87	No
6037123301	0	95	51	76 - 80%	92	53	No
6037121600	49	65	33	76 - 80%	92	49	No
6037121020	0	52	65	91 - 95%	85	84	No
Burbank West							
6037310800	77	99	25	76 - 80%	96	46	Yes
6037310701	64	99	59	81 - 85%	95	61	Yes
6037310702	64	99	54	76 - 80%	92	53	Yes
6037311802	77	99	64	81 - 85%	96	56	Yes
6037311801	77	99	57	71 - 75%	98	40	No
6037301602	77	98	61	91 - 95%	99	57	Yes
6037301601	77	100	80	96 - 100%	100	74	Yes
Verdugo							
6037301702	64	98	63	86 - 90%	100	51	Yes
6037301701	64	95	47	91 - 95%	99	57	Yes
6037301801	64	85	60	91 - 95%	97	67	Yes
6037301100	42	89	25	51 - 55%	85	25	No
6037301900	42	66	52	76 - 80%	94	47	No
6037301000	42	5	58	66 - 70%	87	63	No
6037300800	29	95	32	46 - 50%	84	22	No
Arroyo Seco							
6037460800	29	16	1	46 - 50%	89	19	No
6037461700	29	5	5	51 - 55%	81	32	No
6037463800	42	1	3	41 - 45%	63	30	No
6037463700	29	0	27	45 - 50%	77	28	No
6037463900	42	0	11	61 - 65%	76	44	No
Alhambra							
6037482402	64	97	72	96 - 100%	99	71	Yes
6037433601	0	99	69	96 - 100%	96	89	Yes
6037482401	0	94	73	86 - 90%	92	73	Yes
6037482304	0	82	88	86 - 90%	80	84	Yes
6037482303	0	88	75	86 - 90%	89	77	Yes
6037482301	0	96	74	86 - 90%	91	67	Yes

Tract	Impaired Water	Groundwater Threat	Poverty	Cal Environ Score	Pollution Burden	Population Characteristics	Disadvantaged?
6037481401	0	99	59	76 - 80%	89	59	Yes
6037481500	0	99	43	91 - 95%	98	71	Yes
6037481002	0	100	60	76 - 80%	92	54	Yes
6037480302	0	100	53	51 - 55%	85	26	Yes
Rubio							
6037433601	0	99	69	96 - 100%	96	89	Yes
6037433101	0	100	64	96 - 100%	100	70	Yes
6037432901	0	99	62	91 - 95%	99	63	Yes
6037481300	0	94	63	81 - 85%	96	58	Yes
6037432201	0	97	76	91 - 95%	91	78	Yes
6037481202	0	98	55	81 - 85%	96	54	Yes
6037481102	0	98	58	61 - 65%	96	27	No
Eaton							
6037481201	0	94	54	81 - 85%	98	52	No
6037432102	0	96	31	81 - 85%	98	48	No
6037432202	0	98	50	91 - 95%	99	70	No
6037432902	0	99	43	81 - 85%	98	51	No
6037432802	0	99	97	96 - 100%	99	90	No
6037432801	0	98	68	96 - 100%	99	98	No
Rio Hondo							
6037432401	64	56	79	96 - 100%	91	94	Yes
6037432402	64	85	91	96 - 100%	98	79	Yes
6037432300	0	98	30	76 - 80%	96	45	Yes
6037432801	0	98	68	96 - 100%	99	98	Yes
6037432802	0	99	97	96 - 100%	99	90	No
6037433101	0	100	64	96 - 100%	100	70	Yes
6037432700	0	99	80	96 - 100%	99	81	Yes
6037432402	64	85	91	96 - 100%	98	79	Yes
6037431501	64	16	52	71 - 75%	78	61	Yes
6037431502	64	59	33	66 - 70%	95	35	No
6037432500	72	75	49	86 - 90%	97	66	Yes
6037433102	0	100	94	96 - 100%	97	88	Yes
6037433501	0	100	93	96 - 100%	97	93	Yes
6037433601	0	99	69	96 - 100%	96	89	Yes
6037433602	0	98	78	91 - 95%	92	78	Yes
Big Dalton							
6037407001	42	95	71	91 - 95%	96	70	Yes
6037404703	42	95	76	96 - 100%	100	82	Yes
6037404802	42	77	69	96 - 100%	96	81	Yes
6037404801	42	54	74	96 - 100%	91	89	Yes
6037405201	0	81	75	91 - 95%	95	79	Yes
Walnut							
6037404703	42	95	76	96 - 100%	100	82	Yes
6037407001	42	95	71	91 - 95%	96	70	Yes
6037404803	42	77	57	96 - 100%	97	83	Yes
6037406800	42	43	32	86 - 90%	94	64	Yes
6037406702	42	16	63	86 - 90%	89	77	Yes
6037406500	42	0	15	46 - 50%	85	20	Yes
6037406411	42	0	45	66 - 70%	88	43	Yes
6037406412	42	0	13	51 - 55%	70	35	Yes
San Jose							
6037408140	15	84	82	86 - 90%	92	65	Yes
6037408141	15	46	72	71 - 75%	89	52	No
6037403402	15	26	22	31 - 35%	71	15	No
6037408137	15	36	65	76 - 80%	90	53	Yes
6037408136	15	31	35	56 - 60%	72	43	No
6037408212	15	76	59	71 - 75%	96	40	No
6037403303	15	10	17	61 - 65%	90	34	Yes
6037408302	55	24	40	96 - 100%	100	64	Yes
6037408303	55	5	38	91 - 95%	98	68	No
6037408402	64	26	16	66 - 70%	99	30	No
6037408202	64	99	74	96 - 100%	100	63	Yes
6037408211	15	97	68	71 - 75%	99	35	No
6037408139	15	86	93	91 - 95%	72	72	Yes
Morris Dam							
6037930301	42	32	1	36 - 40%	55	23	No

Tract	Impaired Water	Groundwater Threat	Poverty	Cal Environ Score	Pollution Burden	Population Characteristics	Disadvantaged?
Pacoima Dam 6037930200	0	75	1	68 - 70%	74	52	No
Puddingstone Diversion 6037400207	0	53	12	41 - 45%	58	28	No
San Dimas Dam 6037930301	42	32	1	36 - 40%	55	23	No
San Gabriel Dam 6037930301	42	32	1	36 - 40%	55	23	No
Cogswell Dam 6037930301	42	32	1	36 - 40%	55	23	No
Big Tujunga Dam 6037930200	0	75	1	66 - 70%	74	52	No
Regional Stormwater Capture NSG1 6037132002 6037127605	77 77	16 10	49 85	81 - 85% 86 - 90%	87 87	69 74	No No
USACE Dam 6037980021 6037104108 6037104124 6037103300 6037121102	0 0 0 0 72	0 24 0 31 99	NA 87 56 12 57	NA 91 - 95% 71 - 75% 26 - 30% 91 - 95%	77 81 75 67 98	NA 89 59 12 69	No Yes No No Yes
Regional Stormwater Capture NSG2 6037400603	0	92	29	61 - 65%	93	33	No
Regional Stormwater Capture NSG3 6037430002	0	1	42	71 - 75%	90	50	No
Regional Stormwater Capture NSG4 6037122000	49	79	52	91 - 95%	94	74	No
Regional Stormwater Capture NSG5 6037402402	15	86	56	96 - 100%	100	61	No
Regional Stormwater Capture NSG6 6037201401	0	21	68	61 - 65%	49	66	No
Regional Stormwater Capture NSG7 6037117302 6037117303	0 0	0 46	21 53	51 - 55% 71 - 75%	57 78	41 57	No No
Regional Stormwater Capture NSG8 6037113237	0	33	22	41 - 45%	50	36	No