Memorandum - DRAFT

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Subject: *Austin Water Integrated Water Resources Plan:*
Task No. 2 – Methodology for Options and Portfolio Evaluation. Revised.
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The Water Forward Integrated Water Resources Plan (IWRP) is a comprehensive planning process being undertaken by Austin Water (AW) to evaluate water supply and demand management options. The Mission Statement for the IWRP is as follows:

> *The Integrated Water Resource Plan (IWRP) will provide a mid- and long-term evaluation of, and plan for, water supply and demand management options for the City of Austin in a regional water supply context.*
>
> *Through public outreach and coordination of efforts between City departments and the Austin Integrated Water Resource Planning Community Task Force (Task Force), the IWRP offers a holistic and inclusive approach to water resource planning.*
>
> *The plan embraces an innovative and integrated water management process with the goal of ensuring a diversified, sustainable, and resilient water future, with strong emphasis on water conservation.*

The purpose of this memorandum is to provide an overview of how demand-side and supply options will be screened and characterized. It also establishes the primary objectives, sub-objectives, and performance measures that will be used to evaluate portfolios (combinations of individual options). Above all, it provides the framework for how the IWRP will provide a transparent, unbiased analysis of the tradeoffs between various portfolios to meet the IWRP objectives.

1.0 Preliminary Estimation of Water Supply Needs

An important aspect of the IWRP is to evaluate existing water supplies under different hydrologic conditions and compare these supplies to forecasted water demands. This will provide preliminary estimates of short-term, medium-term and long-term water supply needs. The Colorado River Basin Water Availability Model (WAM) will be used for evaluation of future water supply needs for the forecasted demands in years 2020, 2040, 2070 and 2115, under different hydrologic scenarios which are planned to include the historical hydrologic period of record, climate change adjusted hydrology, and randomized re-sequenced hydrology.

Forecasted demands will be simulated against various hydrologic scenarios, and measures of supply shortage will be produced. No portfolios of water supply or demand-side options will be used in this preliminary water supply needs analysis. The purpose of this assessment will be to gain an understanding of the characteristics of potential water supply needs. Subsequent tasks in the IWRP process will take this and other information into account in the development of portfolios.

1.1 Evaluation Process Overview

The Austin IWRP evaluation process is based on a proven planning process that explores both demand-side and supply-side options in an integrated manner in order to meet multiple objectives. The IWRP process also explores risks and uncertainty related to different potential hydrologic and climatic futures over the next 100 years.

In development of the IWRP, the following terms will be used:

Objectives	• Broadly stated goals of the IWRP that drive the evaluation process.
Sub-objectives	• Adds further clarity to the objectives, and forms the basis for the evaluation criteria used to score portfolios.
Performance Measures	• Metrics that indicate how well sub-objectives are being achieved.
Options	• Individual water supply and demand-side management projects or programs.
Portfolios	• Combinations of options that are evaluated against the performance measures.

The IWRP process is summarized in **Figure 1**. The process begins with defining the objectives, sub-objectives, and performance measures. The sub-objectives together with the performance measures serve as the evaluation criteria by which IWRP portfolios will be measured against.

Prior to developing portfolios, identification and characterization of various water supply and demand-side options will take place. The process will start with a larger number of options, which will be screened down to a smaller number using a set of criteria. These criteria will include a high-level unit-cost comparison and a high-level implementation risk comparison. Those options that pass the screening process will be evaluated and characterized in greater detail. This process of characterization of water supply and demand-side options will be summarized in subsequent technical memoranda.

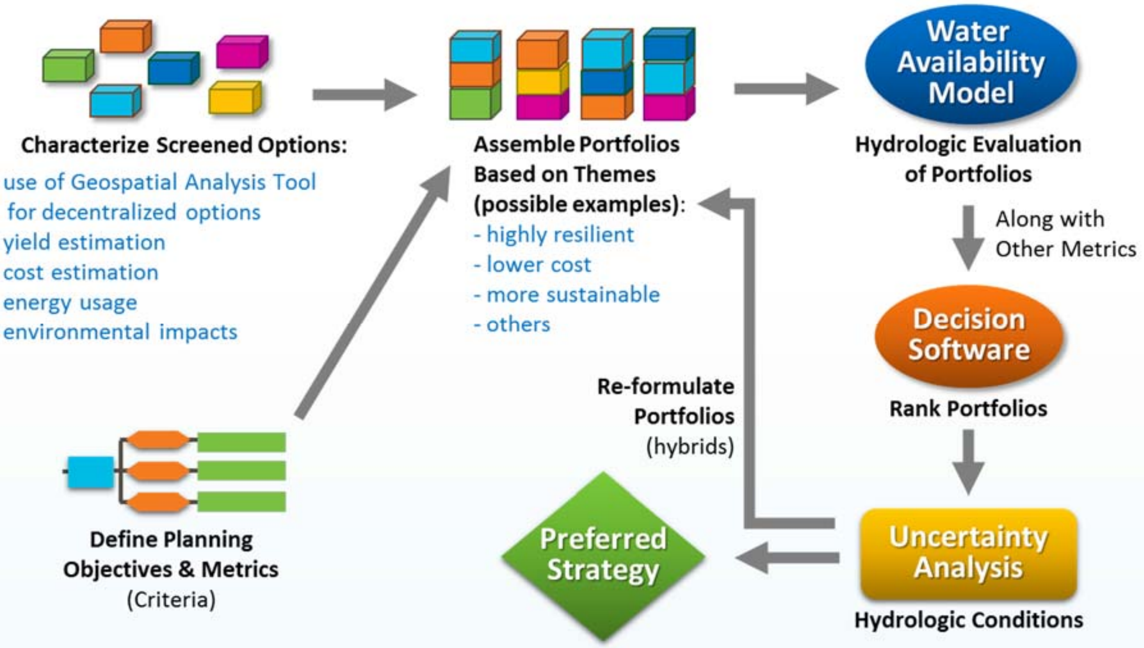

Figure 1 – AW IWRP Planning Process

Because no single option can meet all of the IWRP objectives and sub-objectives, multiple options will be combined in various ways to develop portfolios. The portfolios will be developed around themes such as “High Resiliency” or “Lower Cost” or “High Stewardship”. Themes will be developed by AW with input from the Task Force. Each portfolio will then be evaluated in terms of how well they achieve the sub-objectives, under various hydrologic conditions (for example historical and climate change scenarios). Ultimately, the portfolios will be ranked and a preferred IWRP strategy will be recommended for implementation. The preferred IWRP strategy may be a combination of several high-ranking portfolios using an adaptive management approach that would implement various options within the portfolios based on triggers, such as demand growth, hydrologic conditions and other factors.

1.2 Objectives and Performance Measures

The IWRP planning objectives serve as the framework for how the IWRP is developed. Objectives are usually categorized into primary and secondary (or sub-objectives). Primary objectives are more general, while sub-objectives help define the primary objectives in more specific terms. Note that throughout this memorandum the terms *objective* and *primary objective* are used interchangeably. Based on decision science literature and consulting best practices, sub-objectives should have the following attributes:

- **Be Distinctive:** to distinguish between one portfolio and another
- **Be Measurable:** in order to determine if they are being achieved, either through quantitative or qualitative metrics
- **Be Non-Redundant:** to avoid overlap and avoid bias the ranking of portfolios
- **Be Understandable:** be easily explainable and clear
- **Be Concise:** to focus on what is most important in decision-making

The IWRP objectives and sub-objectives were developed by AW/consultant team, with input from the Task Force. The objectives were formulated based on the previous 2014 Task Force, and centered around principles of sustainability (balanced between economic, environmental, social needs). Initial sub-objectives were formulated with a “defining question” to establish the intent of the sub-objective. A preliminary list of 25 draft sub-objectives was developed as part of a full day workshop held with the AW/consultant team. Based on input from the Water Forward Task Force (previously referred to as IWRP Task Force) through a survey, the sub-objectives were reduced to 14, which aligns well with decision science literature and consulting best practices.

For each sub-objective, a performance measure is required. The performance measure is used to indicate how well a sub-objective is being achieved. Where possible, quantitative performance measures were established based on a review of available data and anticipated output from the various IWRP analyses, tools, and modeling efforts. In certain instances, a qualitative score is the most suitable performance measure. Qualitative scores will be established based on a combination of quantitative analysis, professional judgment, and input from subject matter experts, including AW staff/consultant team. **Table 1** presents the refined list of primary objectives, sub-objectives and performance measures.

In any decision-making process, primary objectives are generally not all equally important. Thus, developing a set of weights is necessary to better reflect the difference in values and preferences among the various objectives. The AW/consultant team will initially develop a draft set of weights for the objectives and sub-objectives. The weighting of objectives from the 2014 Task Force process will be considered in developing the initial draft weighting set.

A survey will be sent out to the Water Forward Task Force with the draft weightings for objectives and sub-objectives that will be used to solicit input on the draft weightings. This survey information will be provided for review and discussion by the Water Forward Task Force. Additional input provided will be considered by AW and the consultant team in the process of refining the weighting set.

Table 1 Objectives, Sub-objectives, Defining Question, and Performance Measures

Primary Objective	Sub-Objective	Defining Question	Performance Measure
Water Supply Benefits	Maximize Water Reliability	How does the portfolio perform in terms of reliability (how often is there shortage), vulnerability (how large is the shortage), recovery (how fast is the recovery from shortages) under various hydrologic conditions (including climate change scenarios)?	Water Supply Index (0 to 1) based on WAM modeling results
	Maximize Local Control	To what extent does AW have control over the quantity and storage of water and operation of options (especially during drought periods) included in the portfolio?	Proportion of total supply yield from locally controlled sources
	Maximize Supply Diversification	How many independent water supply and demand-side management options above a minimum yield threshold are included in the portfolio?	# of supply/demand-side management sources (above minimum yield threshold)
Economic Impacts	Maximize Cost-Effectiveness	What is the total capital (construction) and operations/maintenance costs of all projects/programs in the portfolio over the lifecycle, divided by the sum of all water yield produced by the portfolio?	Unit cost ($/AF) expressed as a present value sum of all costs over the lifecycle, including utility and customer costs.
	Maximize Advantageous External Funding	Does the portfolio have an opportunity for advantageous external funding from Federal, State, local, and private sources?	External Funding Score (1-5), where 1 = low potential and 5 = high potential
Environmental Impacts	Minimize Ecosystem Impacts	To what extent does the portfolio positively or negatively impact receiving water quality (e.g., streams, river, lakes), terrestrial and aquatic habitats throughout Austin, and net streamflow effects both upstream and downstream from Austin?	Ecosystem Impact Score (1-5), where 1 = high combined negative impacts and 5 = high combined positive impacts
	Minimize Net Energy Use	What is the net energy requirement of the portfolio, considering energy generation?	Incremental net change in kWh
	Maximize Water Use Efficiency	What is the reduction in potable water use from water conservation, reuse and rainwater capture for the portfolio?	Potable per capita water use (gallon/person/day)
Social Impacts	Maximize Multi-Benefit Infrastructure/Programs	To what extent does the portfolio provide secondary benefits such as enhanced community livability/beautification, increased water ethic, ecosystem services, or others?	Multiple Benefits Score (1-5), where 1 = low benefits and 5 = high benefits
	Maximize Net Benefits to Local Economy	To what extent does the supply reliability and water investments of the portfolio protect and improve local economic vitality, including permanent job creation?	Local Economy Score (1-5), where 1 = high negative impact and 5 = high positive impact
	Maximize Social Equity and Environmental Justice	To what extent does the portfolio support social equity and environmental justice, with emphasis on underserved communities?	Social Equity and Environmental Justice Score (1-5), where 1 = significant support and 5 = minimal support
Implementation Impacts	Minimize Implementation Challenges	What implementation challenges will the portfolio face in terms of public acceptance, regulatory approval, and legal/institutional barriers?	Implementation Uncertainty Score (1-5), where 1 = high combined challenges and 5 = low combined challenges
	Maximize Scalability	To what extent can the portfolio be incrementally sized over time in terms of supply capacity and demand management?	Scalability Score (1-5), where 1 = small incremental sizing potential and 5 = high incremental sizing potential
	Minimize Technical Feasibility Challenges	To what extent does the portfolio rely on emerging and/or unproven technologies?	Technical Feasibility (1-5), where 1 = high reliance on emerging or unproven technologies and 5 = low reliance on emerging or unproven technologies

1.3 Options Screening and Characterization

Prior to developing portfolios for detailed evaluation, it is important to evaluate individual supply and demand-side options. This allows for more informed portfolio development and ultimately portfolios that are better at meeting overall IWRP objectives. To do this, two key steps are required: options screening and a standardized options characterization process.

1.3.1 Options Screening Method

Approximately 22 water supply options and 25 demand-side options will be identified for initial screening by AW/consultant team. Through the screening process these 47 options will be narrowed down to a total of 20 supply and demand-side options (10 supply-side and 10 demand-side) that will be carried forward for further characterization. The anticipated list of options identified for screening will fall under the following main categories:

- Surface Water Supply Options
- Aquifer Storage and Groundwater Options (for example, desalination of brackish groundwater)
- Decentralized Options (for example, graywater/black water, rainwater harvesting)
- Reuse Options
- Water Conservation Options

The screening process will compare a high-level, order-of-magnitude unit cost of the options to an index score of implementation risks created specifically for option screening. The intent would be to plot all of the options for these two parameters to see where outliers exist (meaning those options that have higher unit costs and higher implementation risks). The outlier options would be recommended for elimination from more detailed characterization.

1.3.2 Options Characterization Method

For options carried forward from screening to portfolio evaluation a summary characterization will be developed. Each of these options will be characterized using a standardized *Options Characterization Template* (including, for example, estimated yield and cost). The resulting set of characterized options will be used as a "menu" for forming thematic portfolios (for example, a portfolio that has "High Resiliency" as its theme, as described in more detail below). A list of the characterization metrics, associated units, and a metric definition are provided in **Table 2** for demand management options and **Table 3** for supply options. Option characterizations will be based on the best available technical information; however, more detailed analysis of these options will be required prior to implementation.

Table 3 Demand Management Options Characterization Template

Metric Name	Unit	Metric Definition
Average Annual Yield	AFY	The estimated average annual demand savings achievable by the measure
Supply Type	Qualitative Selection	Annual or emergency/drought
Unit-Cost	$/AF	Total annual cost of the measure for both the utility and the customer minus cost savings from reduced water production and wastewater treatment costs (in 2017 dollars) divided by the estimated average annual yield
Benefit Cost Ratio	Ratio	Average annual yield divided by the unit cost
Climate Resiliency	Qualitative Index	The relative susceptibility of an option to future hydrologic variability
Advantages	Qualitative Description	Narrative on positive attributes of option, including as it relates to portfolio evaluation sub-objectives
Disadvantages	Qualitative Description	Narrative on negative attributes of option, including as it relates to portfolio evaluation sub-objectives

Table 3 Supply Options Characterization Template

Metric Name	Unit	Metric Definition
Estimated Yield	AFY	The estimated incremental average annual new supply (or demand saving) to AW
Supply Type	Qualitative Selection	Annual or emergency/drought
Unit-Cost	$/AF	Total annual cost of the option (in current dollars) divided by the new supply yield. Cost will include both customer and utility perspectives and will include a high-level estimate of likelihood of use if designated as an emergency/drought-only supply
Climate Resiliency	Qualitative Index	The relative susceptibility of an option to future hydrologic variability
Advantages	Qualitative Description	Narrative on positive attributes of option, including as it relates to portfolio evaluation sub-objectives
Disadvantages	Qualitative Description	Narrative on negative attributes of option, including as it relates to portfolio evaluation sub-objectives

1.4 Portfolio Development and Evaluation

Options carried forward from screening and through characterization will be available for inclusion in IWRP portfolios. Water supply and demand-side options will be combined into portfolios that will meet supply needs under different hydrologic scenarios to various degrees of reliability.

Portfolios will be formed based on objective-based themes and then evaluated against the IWRP sub-objectives and performance measures. While the IWRP will produce analyses and demand/supply comparisons for the forecast years 2020, 2040, 2070, and 2115, portfolios will be compared and ranked using the planning year 2070. The selection of 2070 for the purposes of ranking portfolios was based on several factors, including: (1) it represents a long-term forecast that has more certainty than 2115, and (2) it aligns with the Texas Regional Water Planning process.

1.4.1 Method for Formulation of Portfolios

No single option can meet all of the stated IWRP objectives. Therefore, options are combined to form portfolios. The number of potential combinations of options (i.e. portfolios) is too large to produce a meaningful analysis for the AW IWRP. As a result, portfolios will be developed around major themes that align with the IWRP objectives. For example, what would a portfolio look like if the only objective is to maximize supply resiliency? Based on the options characterization results we can develop a portfolio whose sole focus is on supply resiliency and does not consider other objectives such as cost or environmental impact. By developing these initial portfolios that "push" the bounds of each of the most important objectives, trade-offs can be easily identified which can then provide insights in developing "hybrid" portfolios that are more balanced and have a better likelihood of meeting numerous objectives well.

Initial thematic portfolios will be developed by the AW/consultant team based on input from stakeholders, including the Water Forward Task Force. A list of example portfolio themes is provided below for illustration purposes only.

- **High Resiliency** – Options included in this portfolio are those that have little to no hydrologic variability (and therefore not subject to droughts or climate change)
- **Lower Cost** – Options included in this portfolio are those that have a lower unit cost ($/AF)
- **High Stewardship** – Options included in this portfolio are those such as conservation, water reuse, rainwater harvesting.
- **Maximize Local Control** – Options included in this portfolio are those in which AW has more control over terms of cost, yield, development, and operations in the future

- **Hybrid** – A hybrid portfolio will build on one or a combination of initial thematic portfolios to provide more balance and improved performance as it related to the IWRP sub-objectives

1.4.2 Portfolio Evaluation Method

When evaluating a diverse set of portfolios against multiple objectives it is not possible to find a single portfolio that meets the needs or priorities of every stakeholder. Instead, the goal is to evaluate trade-offs between options and objectives, which will be used make an informed decision on selecting a preferred portfolio. To do this, the AW IWRP will utilize multi-criteria decision analysis (MCDA) to evaluate portfolios. The MCDA process will rely on the performance measures and performance weights (outlined in previous sections) and a suite of tools. It is important to note that final recommendation will be "human-based," not computer model-based.

Overview of IWRP Tools

The software Criterium Decision Plus (CDP), developed by Infoharvest Inc., will be the primary software used to conduct MCDA; however, it will be dependent upon input from other IWRP tools and also input from stakeholders and subject matter experts. Each portfolio will undergo modeling and assessment that will generate raw quantitative and raw qualitative performance measure scores. **Figure 2** shows the portfolio evaluation workflow of IWRP tools. The below tools will serve a major role in development of performance measure scores for the AW IWRP:

- **Colorado Basin Water Availability Model (WAM)** – computer-based simulation model, developed and used by the Texas Commission on Environmental Quality (TCEQ) quantifying the amount of water that would be flowing in the Colorado River and available to water rights under a specified set of conditions (e.g. water use, naturalized hydrology, etc.)

- **Geospatial Decentralized Supply Suite of Tools** –set of geospatial analysis processes that evaluates the end user demands, supply yield, cost, and avoided costs associated with storm/gray/black water capture infrastructure

- **Disaggregated Demand Forecasting Model** – end-use based water demand forecast model including residential, multifamily, and commercial sectors; includes impacts of conservation (including Drought Contingency Plan implementation), weather and climate, and price of water.

- **Portfolio Evaluation Spreadsheet Tool** – spreadsheet tool utilized to assemble options into portfolios based on supply needs (difference between existing supplies and future demands under different hydrologic scenarios), and will estimate total portfolio costs from individual unit costs for each option.

- **Criterium Decision Plus** – an industry-leading commercial software to compare and rank portfolios based on multiple criteria (see below for detailed description).

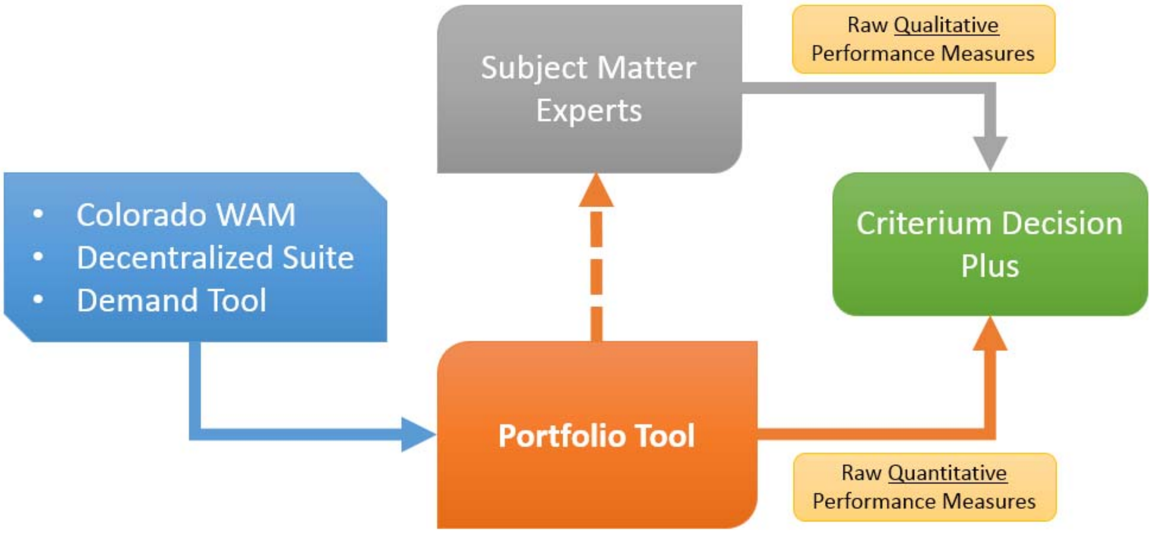

Figure 2 – IWRP Tool Portfolio Evaluation Workflow

Description of Water Availability Model Use in Portfolio Evaluation

In order to evaluate the robustness of the portfolio rankings, each portfolio will be evaluated and ranked under four hydrologic scenarios:

1. **Historic Hydrology**: based on the historical period of record from 1940 to 2016 maintaining the historical sequence of years.
2. **Extended Sampling of Historic Hydrology** : based on an extended 10,000 year simulation made up of resequenced years from the historic hydrology, this sequence is used to develop a range of conditions worse than the drought of 2007-2016
3. **Historic Hydrology with Climate Change Adjustments** : based on a climate change scenario ensemble that adjusts the historical hydrology, but maintains the historical sequence of years.
4. **Extended Sampling of Historic Hydrology with Climate Change Adjustments**: based on an extended 10,000 year simulation made up of resequenced years from the climate change-adjusted historic hydrology, this sequence is used to develop a range of conditions worse than the drought of 2007-2016

Additional detail related to each future climate condition will be established in future technical memorandums and in coordination with AW climate change and hydrology consultants. For each future hydrologic and climate condition new raw performance measure scores will be generated for each portfolio and entered into CDP for ranking. Not all performance measure scores will be impacted by a change in future climate conditions; however, sub-objectives such as Maximize Water Reliability, Minimize Life-cycle Unit Cost, and Minimize Ecosystem Impacts are likely to show some level of sensitivity. CDP will be utilized to efficiently develop portfolio rankings unique to each future hydrologic or climate condition. This analysis will establish whether or not a portfolio is robust as related to hydrologic and climate change uncertainty.

Description of Criterium Decision Plus Software

Criterium Decision Plus (CDP) will be used to rank portfolios. This software tool converts raw performance measured in different units into standardized scores so that the performance measures can be summarized into an overall value. Through CDP, a multi-attribute rating technique will be applied to score and rank the selected portfolios. One advantage of the multi-attribute rating technique is that the resulting scores are non-relative and thus not dependent on the number of portfolios. This allows for the addition of portfolios, such as hybrid portfolios, without impact to the scores of those portfolios previously evaluated. **Figure 3** summarizes the multi-attribute rating technique that is used by CDP to compare and rank portfolios.

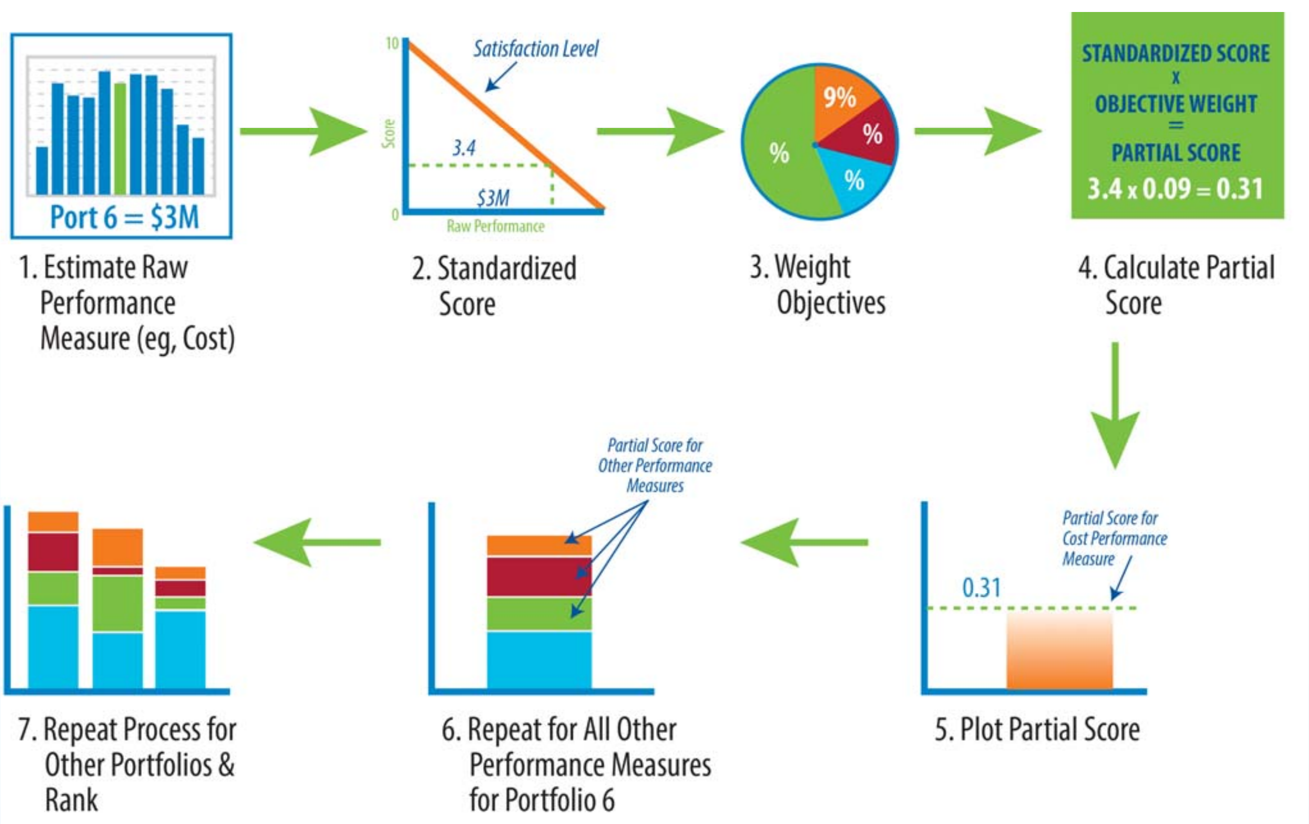

Figure 3 – Multi-Attribute Rating Technique Used by CDP Software to Rank Portfolios

Multi-attribute rating uses 7 steps to score and rank portfolios. In step 1, raw performance for all of the portfolios is compared for a given criterion (in this case cost). Step 2 standardizes the performance into a score from 0 to 10. In this example, Portfolio 6's cost performance is fairly expensive so its standardized score is fairly low (e.g., 3.4 out of 10). This step is important because performance is measured in different units (i.e., cost in dollars, reliability in AFY). Step 3 assigns weights to the objective and Step 4 calculates a partial score for a given portfolio based on the multiplication of the standardized score (Step 2) and weight (Step 3). The partial score is plotted (Step 5), and then the whole process is repeated for a given portfolio for all of the other performance measures (Step 6). This creates a total score that can then be compared to other portfolios. Steps 1-6 are repeated for all portfolios and compared so they can be ranked (Step 7).

Example of Portfolio Ranking

As outlined above, there are two primary inputs to CDP: (1) raw performance of a portfolio against each performance measure; and (2) the relative importance of the objectives and performance measures (see **Figure 4**).

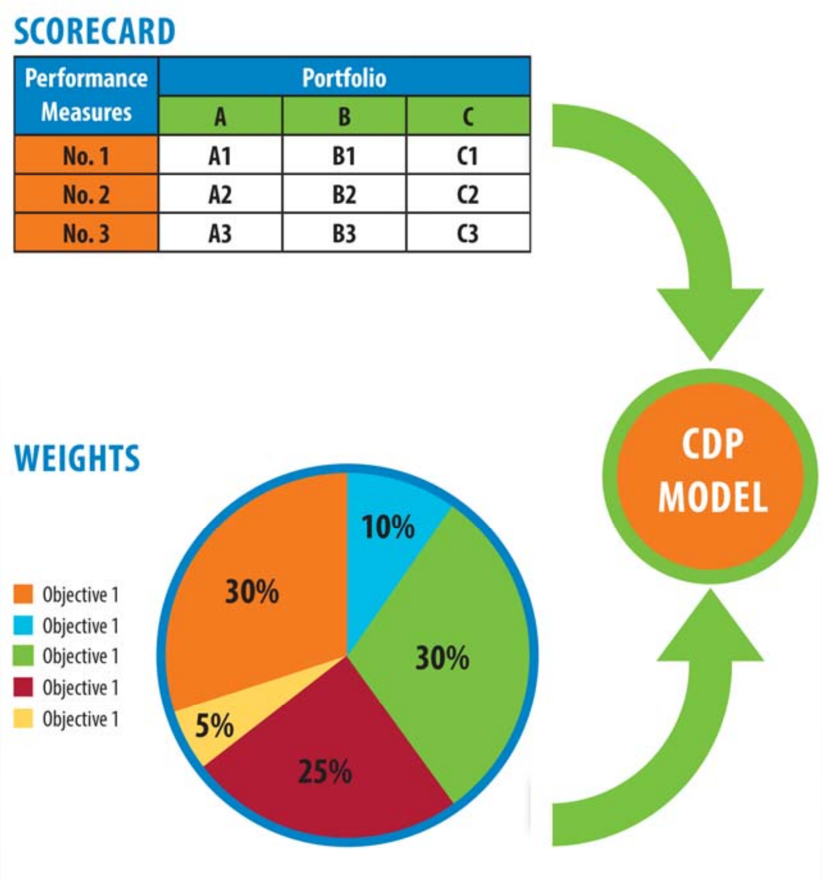

Figure 4 – Inputs to CDP

The raw performance measure scores will be standardized by CDP to a unitless scale that ranges from 0 to 1 using the multi-attribute rating technique (described above). The CDP model will then multiply the unitless performance scores by the relative weight of each associated sub-objective. These weighted unitless scores are then aggregated to the objective level and an overall portfolio score will be determined. This process is repeated for each portfolio and the portfolios are ranked based on their overall scores. **Figure 5** presents an example of how portfolios are ranked based on a set of primary objectives and their weights of importance. This process is powerful because it not only ranks portfolios but clearly shows trade-offs between the objectives.

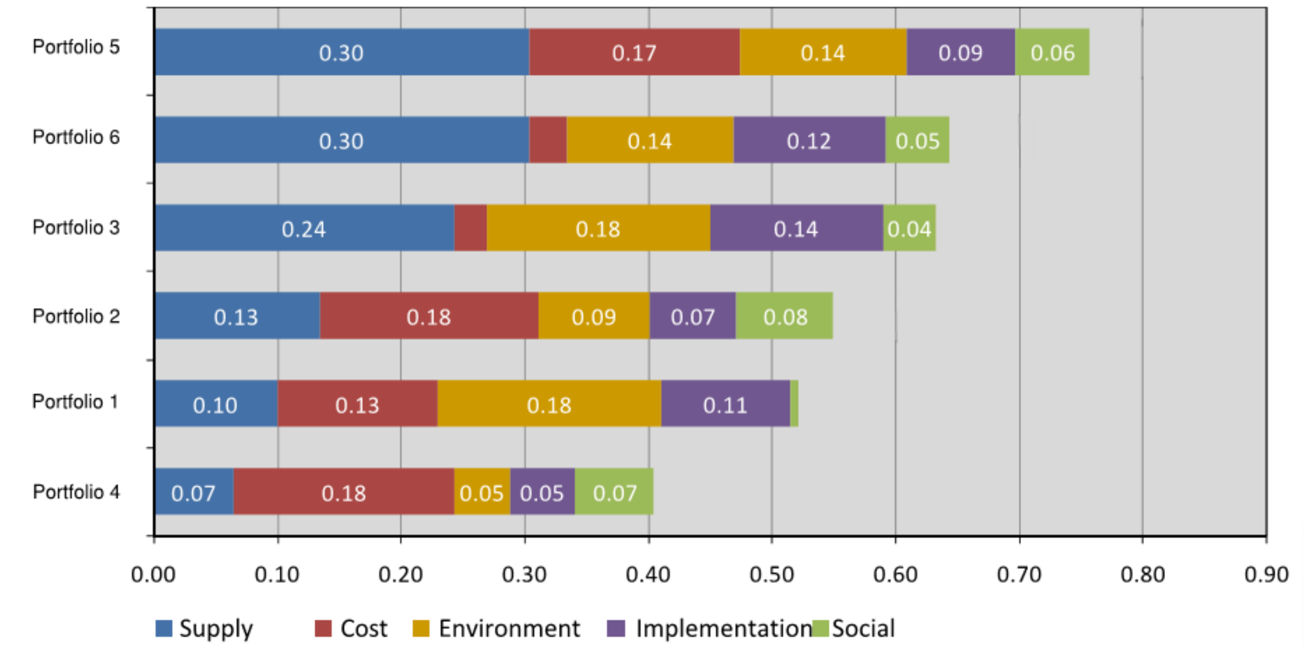

Figure 5 – Illustrative Example of Portfolio Ranking Using CDP Software

In this example of portfolio ranking, the larger the color bar segments the better the portfolio performs for a given objective. For example, Portfolio 5 has the best supply reliability and hence the longer bar segment for the supply objective. Portfolio 6 also has the best supply reliability score, but it is not as cost-effective (meaning it is higher in cost) than Portfolio 5 and hence it has a relatively small bar segment for the cost objective.

1.4.3 Sensitivity Analysis Method

An evaluation of the sensitivity of the portfolio rankings to the initial baseline objective weights will be performed. Several sensitivities will be conducted by altering the relative weights of the primary objectives. For example, in addition to the baseline weighting set, alternate weighting sets similar to the below list will be evaluated using CDP:

- All objectives are weighted equally, at 20 percent each
- Implementation Impacts are given a super weight of 40 percent, while all other objectives are given a weight of 15 percent each.
- Economics Impacts (or Cost) is given a super weight of 40 percent, while all other objectives are given a weight of 15 percent each

Table 3 indicates that example Portfolio 5 ranks 1st in three out of four weighting sets, and only when implementation is given a super weight does it rank 3rd. Example Portfolio 6, ranks 2nd in two out of four weighting sets and only ranks 1st when implementation is given a super weight. However, when cost is given a super weight example Portfolio 6 ranks 5th (second-to-last). All other portfolios never rank 1st and rarely are consistent in their ranking of 2nd and 3rd places. This sensitivity analysis indicates that the evaluation and ranking of portfolios is fairly robust.

Table 3 – Portfolio Ranking Sensitivity to Different Objective Weighting Sets

Weighting Set	Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6
Baseline Weights	5	4	3	6	1	2
Equal Weights	6	3	4	5	1	2
Implementation Weight	5	4	2	6	3	1
Economic Weight	4	2	6	3	1	5
Average Ranking	**5.0**	**3.3**	**3.8**	**5.0**	**1.5**	**2.5**

The portfolio evaluation method provides a fair comparison of the portfolios through the use of CDP's multi-attribute rating technique combined with a sensitivity and uncertainty analysis. This approach will ensure that AW secures a diversified, sustainable, and resilient water future for the Austin community.