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memorandum

date	September 10, 2018
to	Stephanie Gaines, County of San Diego
cc	
from	Hennessy Miller, Lindsey Sheehan, P.E., David Pohl, Ph.D., P.E., ESA
subject	San Diego Stormwater Capture and Use Feasibility Study – Cost Analysis (FINAL)

The San Diego Stormwater Capture and Use Feasibility Study (SWCFS) is designed to provide a regional analysis of the feasibility of planning, constructing, operating, and managing facilities that capture and use stormwater. The goals of the SWCFS include:

- Quantify the range of stormwater that could be potentially captured and stored on public lands and used in the San Diego region;
- Identify the opportunities and constraints for a range of stormwater capture and use examples for use as a management tool in the development and planning of similar projects; and,
- Prioritize the potential stormwater use alternatives on screened public parcels on a short-, mid- and long-term timeline basis.

The quantification goal is achieved by first screening applicable public parcels using a set of criteria that is specific to each stormwater use alternative. This is a more refined analysis than was conducted for the San Diego Region Stormwater Resource Plan (SWRP) (ESA, 2017a) by applying specific parcel screening criteria that accounted for site and technical constraints and modeling more of these sites for specific use alternatives. Eight stormwater use alternatives were identified during methods development.

Example stormwater capture and use projects were analyzed for opportunities and constraints. The project examples were obtained from existing SWRP and Integrated Regional Watershed Management Plan (IRWMP) project lists and input from the SWCFS Technical Advisory Committee (TAC). These examples were developed to provide a tool for managers to evaluate what types of projects may be feasible for a parcel that is under consideration for a stormwater capture and reuse project. Informed by the parcel analysis, managers may use both the parcel analysis and the example projects to conduct a project specific and more detailed assessment of the opportunities and constraints for each individual parcel at a project-level, even if the parcel was not identified in this study.

Prioritization will identify the short-term potential use alternatives that have fewer constraints to implementation. These short-term opportunities provide for potential regional planning for these types of projects. Through this analysis, regional constraints to implementing stormwater capture and use will be identified. The SWCFS can be a tool to guide the region over time to address those constraints that can be overcome, such as regulatory constraints and clarity. Overcoming these constraints or "gates" will allow some of short and potentially mid-term projects and alternatives to move forward towards implementation.

In coordination with the TAC, the County of San Diego is developing the SWCFS through a multi-step process. The first step was an extensive data collection effort, documented in the first technical memorandum (ESA 2017b). Next, the methods to quantify the potential stormwater capture and use and identify potential projects opportunities and constraints were developed and documented in the second technical memorandum (ESA 2017c). The quantification results were then presented in the Modeling Approach and Results Technical Memorandum (ESA 2018)[1]. This report summarizes the methods and presents the results of the conceptual-level cost analysis. The final step will be the prioritization of the public parcel alternatives for the region.

Conceptual costs were developed by both the case study example projects and the parcels identified in the quantification analysis. The costs developed for the example projects will help further develop the opportunities and constraints for these types of projects. The costs developed for the parcels will provide an additional factor for the parcel project prioritization, which will be the final step of this study. However, it is important to note that the costs used within this memo are used to prioritize use alternatives at a high-level, only to support planning and water management efforts. Actual project costs will vary depending on watershed or sewershed, infrastructure technology, treatment requirements, and other project-specific variables. This memo provides a range of costs to try to cover this variability, but actual costs for projects should be analyzed and refined on a project by project basis.

Section 1 of this memo presents the methods of this conceptual-level cost analysis. Section 2 provides the results and conclusions of the analysis with example project costs included in Attachment A.

1. Cost Analysis Methods

1.1 Parcel Analysis Quantities

As described in ESA 2018, a parcel analysis was completed to identify the most feasible public parcels for a stormwater capture and use project. A subset of the identified parcels (67 parcels) were modeled in ESA 2018 to determine the volume of stormwater that could be captured and used. Conceptual quantities were developed for each of these parcels, including basin or vault acreage and depth and distance to end use. These projects and quantities provided the basis for the cost analysis.

1.2 Unit Costs

The unit costs were determined based on a review of the literature (Grey et. al. 2013), costs of built projects, and the RSMeans costing program. Professional judgement was used to select the most applicable cost where multiple

[1] http://www.projectcleanwater.org/download/swcfs-analysis-results/

unit costs for individual items were identified. The feasibility-level cost estimates were developed for comparative purposes, so more refined cost analysis should be completed at the project-level.

1.2.1 Unit Costs from the Literature

To estimate costs for infiltration and biofiltration basins, Grey et. al. 2013 provides a review of the literature on stormwater best management practices (BMP) or project costing. The paper provides unit costs for infiltration basins, infiltration pavers, and biofiltration facilities using costs per square foot of impervious area, per gallon of design volume, and per square foot of BMP. A subsequent study (Western Riverside Council of Governments 2016) found that the costs based on literature values do not necessarily scale up with the size of the BMP, resulting in some of these costs being unrealistically high. To narrow the range of costs while still being conservative, infiltration pavers costs, which were an outlier, were dropped from the analysis and the price per gallon of design volume was used (and converted to price per acre-foot (ac-ft)).

Additionally, references were used for the cost of treatment for recycled and potable water. These references included Raucher and Tchobanoglous (2014), Cooley and Phurisamban (2016), and the California Urban Water Agencies White Paper (2016), "The Potential for Stormwater as a Water Supply".

1.2.2 Unit Costs from Example Projects

Unit costs were also estimated based on construction bids for projects that are currently or have already been built. For example, the Big Canyon Wetland Treatment and Creek Restoration project in Newport Beach received bids for constructing a stormwater treatment wetland, dry-weather flow diversions, and culvert improvements. Additional sources of data came from projects recently completed in Los Angeles (Franklin D. Roosevelt Park), Newport Beach (Big Canyon Restoration), and San Clemente (Poche Beach Bacterial Disinfection Project), using construction elements currently in place and actual costs.

1.2.3 Unit Costs from RSMeans Costing Program

Another method of developing unit costs was based on a costing program called RSMeans using the 2018 Building Construction Cost Book, the most widely used construction cost database available. RSMeans tracks labor and material cost changes to provide the most up to date and reliable information. The costs were keyed to Southern California city cost indexes, productivity rates, crew composition, and contractor's overhead and profit rates.

1.2.4 Unit Costs from Manufactured Units

A fourth method for developing unit costs was using manufactured units with defined costs. For example, concrete detention vault costs were based on planning-level information provided by Oldcastle Precast for their StormCapture® System. Material costs range from $6 - $10 per cubic foot of storage volume. A 5-percent average of the material cost was added to approximate the cost of setting the modular components.

1.3 Cost Assumptions for Each Stormwater Use Alternative

Certain assumptions were needed to develop the costs for each stormwater use alternative. For example, to be able to capture the range of possible costs for each alternative, both a low and high estimate were used for each line item assumption. The cost components and assumptions are further discussed below. Attachment B provides tables showing example project costs, which include both the low and high costing assumptions, resulting in a project cost range.

1.3.1 Alternative A, Infiltration to Groundwater Basin

1.3.1.1 Infiltration Basins

The cost analysis for infiltration basins under Alternative A included site clearing and erosion control, excavation, final grading, and re-vegetation (Table B-1). The costs included a high and low assumption for the placement of excavated material (i.e. on-site versus off-site), the distance between the MS4 outfall and infiltration basin (i.e. 0 to 250 feet), and the distance between the infiltration basin and a groundwater basin (i.e. 0 to 1 mile). The distance from the MS4 outfall to the infiltration basin would determine whether the MS4 outfall discharged directly to the infiltration basin or if 250 feet of culvert conveyance was required to route stormwater flows from the outfall to the basin. A maximum culvert distance of 250 feet was used based on the parcel analysis criteria (ESA 2018). Similarly, the distance from the infiltration basin to the closest groundwater basin could be up to 1 mile based on the parcel analysis. Costs for extracting groundwater and treating it are not included in this analysis. It is assumed that since the parcels are located near designated groundwater basins, the basins are already being utilized, so infrastructure for extraction is in place.

1.3.1.2 Injection Wells

The cost analysis for injection wells included costs associated with land clearing, excavation, installation of a dry injection well, Title 22 pre-treatment, re-grading, and re-vegetation. The quantification analysis assumed one injection well per parcel (ESA 2018). The costs included a high and low assumption for conveyance distance between the MS4 outfall, the storage basin (i.e. 0 to 250 feet) and placement of excess excavated material (i.e. on-site versus off-site). A project example of costs for injection wells is detailed in Table B-2 in Attachment B. Costs for extracting groundwater and treating it are not included in this analysis. It is assumed that since the parcels are located near designated groundwater basins, the basins are already being utilized, so infrastructure is in place.

1.3.2 Alternative B, Infiltration to Reestablish Hydrology

1.3.2.1 Infiltration Basins

The cost analysis for infiltration basins under Alternative B was almost identical to the infiltration basins under Alternative A, except costs to account for the distance between the infiltration basin and groundwater basin were not included, since Alternative B considers infiltration for hydrologic improvements, and not necessarily to a potable groundwater basin. Table B-3 in Attachment B shows an example cost analysis, which includes both the low and high costing assumptions and provides a range in total cost.

1.3.2.2 Biofiltration Basins

The cost analysis for biofiltration basins included many of same items as the Alternative B infiltration analysis, as well as additional costs uniquely associated with biofiltration, such as aggregate, media, and a draining system. High and low cost assumptions were made regarding basin length (i.e. 500 – 2,400 feet). These values represent the size of a square basin based on the average parcel size in the parcel analysis, and 1.5 times the maximum square basin. Table B-4 in Attachment B details the item and unit cost for each component included in the biofiltration analysis.

1.3.3 Alternative C, Irrigation Projects

The cost analysis for irrigation quantified the costs of site preparation, excavation, conveyance, irrigation, maintenance, and re-vegetation. The analysis evaluated low and high cost assumptions for the placement of site material (i.e. on-site versus off-site), conveyance distance between the MS4 outfall and the storage vault (i.e. 0 to 250 feet), and treatment prior to irrigation (i.e. no additional treatment following initial solids/trash removal versus high end Title 22[2] treatment). Table B-5 in Attachment B details an example cost calculation for Alternative C for both low and high costing assumptions.

1.3.5 Alternative E, Restoration and Treatment Wetland

Costs for restoration and treatment wetlands included site preparation, excavation, vault installation, backfill, and conveyance to the site. High and low assumptions for Alternative E were made for costs associated with material placement (i.e. on-site versus off-site) and conveyance distance between the MS4 outfall and storage vault (i.e. 0 to 250 feet). Table B-6 in Attachment B details an example cost evaluation for Alternative E using both the low and high assumptions.

1.3.6 Alternative F, Dry-Weather Flow Diversion to a Wastewater Treatment Plant

Costs for dry-weather flow diversion to a wastewater treatment plant for recycled water use included site preparation and excavation, installation of a dry-weather diversion pump, a one-time sewer connection fee, an annual sewer fee, and re-vegetation. Alternative F assumed low and high estimates for excavated material placement (i.e. on-site versus off-site). Unit costs for an example parcel are shown in Table B-7 in Attachment B.

1.3.7 Alternative G and H, Flow Diversion to a Wastewater Treatment Plant

Costs for Alternative G (diversion to a wastewater treatment plant for recycled water use) and Alternative H (diversion to wastewater treatment plant for potable water use) included project implementation and diversion structures. Low and high assumptions were made for excavated material placement (i.e. on-site versus off-site).

Cooley and Phurisamban (2016) provide a range of treatment costs for small (<10,000 ac-ft/year) indirect potable and non-potable reuse systems that range from $550 per ac-ft to $2,200 per ac-ft. The parcels modeled for Alternatives G and H have annual capture volumes between 0.4 and 38 ac-ft, so the treatment costs associated with such small capture volumes likely underestimate the minimum treatment cost required for potable and recycled water use. Black & Veatch (2018) developed costs for treatment that would be implemented through a one-time sewer connection fee and an annual sewer fee based on volume. Based on their analysis, the following cost scheme was developed:

- < 5 ac/ft = $30,000 connection fee, $5,000 annual fee

[2] Title 22 of California's Water Recycling Criteria refers to California state guidelines for how treated and recycled water is discharged and used. The standards also require the state's Department of Health Services to develop and enforce water and bacteriological treatment standards for water recycling and reuse. However, whether or not Title 22 would apply to irrigation projects is unclear at this time.

- 5-10 ac/ft = $75,000 connection fee, $20,000 annual fee
- > 10 ac/ft = $150,000 connection fee, $50,000 annual fee

Unit costs for an example parcel are shown in Table B-6 in Attachment B.

1.4 Other Assumptions

For all of the alternatives, it was assumed that planning, engineering, and permitting would constitute approximately 20% of the total cost, and operations and maintenance would constitute approximately 10% of the total cost (15% was assumed for Alternatives F-H where ongoing monitoring and sampling would be included). Additionally, a 20% contingency cost is included in the cost estimates in Attachment B to capture the level of uncertainty for this high-level assessment. These values are typical assumptions for conceptual-level planning.

2. Conceptual-Level Costs and Conclusions

Using the unit costs and assumptions discussed in Section 1, project costs were developed for each of the parcels modeled in ESA 2018. Then, assuming a 25-year lifespan for all projects, a cost per ac-ft of stormwater was calculated based on the total project cost (construction infrastructure) divided by the total (sum) capture volume over the assumed 25-year project lifespan. Table 1 below provides a range of the total project costs and costs per ac-ft of stormwater capture and use for each alternative.

The unit costs developed and presented in Table 1 may be compared to the cost for imported water, water provided by desalination and expected costs for in-direct potable use. These costs are shown in Table 2. It is likely that these costs may change over time due to energy cost increase or other reasons, and future studies should continue to use the most current rates for comparisons.

TABLE 1

PARCEL COST ANALYSIS BY ALTERNATIVE

Alternative	Project Type	Project Size (ac)	Total Project Cost	Cost per Volume ($/ac-ft)
Alternative A	Infiltration	0.4 – 24.7	$233,900 - $7,449,400	$240 - $89,400
	Injection	0.4 – 6.4	$757,900 - $2,316,600	$200 - $31,000
Alternative B	Infiltration	0.2 – 9.4	$205,800 - $2,677,700	$240 - $77,500
	Bio-Infiltration	0.2 – 9.4	$275,400 - $4,815,600	$380 - $138,900
Alternative C	Irrigation	0.1 – 4.7	$1,479,000 - $18,747,300	$38,000 - $638,200
Alternative D	Rain Barrels	-	$125	$2,500
Alternative E	Restoration and Treatment Wetlands	0.1 – 2.9	$185,800 - $1,451,900	$270 - $2,100
Alternative F	Dry-Weather Diversion	0.3 – 12.5	$2,501,300 - $3,267,000	$7,400- $9,600
Alternatives G and H	Wastewater Diversion	0.3 – 12.5	$1,914,300 - $11,732,100	$12,700 – $388,600

TABLE 2

COST OF ALTERNATIVE WATER SUPPLY

Water Supply Source	Cost ($/ac-ft)
Imported Water[1]	$1,546 - $1,603
Indirect Potable Use[2]	$1,100 - $2,200
Desalination[1]	$2,131 - $2,397

1. San Diego County Water Authority 2016 and 2017
2. Cooley and Phurisamban 2016.

2.1 Alternative A

2.1.1 Infiltration Basins

The total project cost for infiltration projects under Alternative A ranged from $233,900 - $7,449,400. The highest costs were for excavation and placement of excavated material and conveyance from the infiltration basin to the groundwater basin (assuming the high-end assumption of 1 mile of conveyance). Excavation costs ranged from 12 to 21 percent of the total project cost, while placement ranged from 18 to 25 percent based on either placement on-site or off-haul. When conveyance to a groundwater basin 1 mile away was considered, the cost, at $422,400, represented, on average, 30 percent of the total cost.

The high-end assumption of 250 feet for conveyance between an MS4 outfall and the infiltration basin was only 1 percent of the total cost, which was relatively insignificant. Conversely, assumptions for placement or off-haul of excavated material and distance between the infiltration basin and groundwater basin were much more significant to the final cost. The analysis indicates that projects directly above or relatively close to groundwater basins and where excavated material can be used on-site are more likely to be economically feasible.

Many of the costs (erosion control and temporary fencing, parcel clearing, excavation, and placement of site material) were directly dependent on the acreage of the infiltration basin; as basin acreage increased, total project cost increased. Interestingly, this indicates that economy of scale may not be a factor for infiltration basins.

The cost per volume for the 17 modeled parcels ranged from $240 to $89,400 per ac-ft. The large range is a result of the range in capture volumes, as well as costs. While costs scale proportionally to infiltration basin size, the capture volume does not. Using the low-end assumptions, 5 of the 16 sites resulted in costs within or below the highest existing water cost (Table 2), and with the high-end assumptions, this drops to 4 sites.

2.1.2 Injection Wells

The average cost of injection well projects ranged from $757,900 - $2,316,600. The cost of the injection well structure itself ($147,000 per well) was a large portion of the total budget at 12 – 31 percent of the total cost. However, when stormwater treatment is required prior to injection, the treatment cost represents on average, 52 percent of the total project cost.

Similar to the cost analysis for infiltration basins, the assumption of 250 feet for conveyance between an MS4 outfall and the infiltration basin resulted in a very minor cost (~1 percent of the total cost), while the decision to place excavated material on-site versus hauling it off-site has a much bigger influence on the cost. Like infiltration projects, injection well project costs scale with the area of the storage basin.

The cost per volume ranged from $200 - $31,000 per ac-ft, but was, on average, lower than the cost for the infiltration projects. This is likely the result of a higher average capture volume (79 ac-ft/year for injection wells compared to 15.6 ac-ft/year for infiltration basins). Four of the six sites resulted in costs below the cost of desalination (Table 2) under both low and high assumptions.

2.2 Alternative B

2.2.1 Infiltration Basins

Infiltration basins under Alternative B had lower costs than the basins under Alternative A, since infiltration directly to a groundwater basin is not needed. Total costs ranged from $205,800 - $2,677,700. Like infiltration basins under Alternative A, the highest costs associated with the infiltration basins under Alternative B were excavation and placement of excavated material. Average excavation costs ranged from 15 to 20 percent of the total cost, while placement ranged from 17 to 32 percent depending on whether material was placed on-site or off-hauled.

As was the case for infiltration basins under Alternative A and injection wells, the assumption of 250 feet for conveyance between an MS4 outfall and the infiltration basin resulted in a very minor cost (~4 percent of the total cost), while the decision to place excavated material on-site versus hauling it off-site has a much bigger influence on the cost. Additionally, infiltration basin project costs scale with the area of the infiltration basin.

The cost per volume ranged from $240 - $77,500 per ac-ft. Using the low-end assumptions, 11 of the 65 sites resulted in costs below the cost of desalination, and with the high-end assumptions, 9 sites had unit costs within or lower than the existing water costs found in Table 2. The higher cost per volume range is likely due to the lower average capture volumes (7 ac-ft/yr) compared to the infiltration basins under Alternative A and the injection well projects.

2.2.2 Biofiltration Basins

The biofiltration project cost analysis yielded higher total project costs than infiltration basins, due to the additional costs uniquely associated with the biofiltration system. Total costs ranged from $275,400 - $4,815,600. The highest costs items for biofiltration were those associated with soil placement (9 – 18 percent of the total cost) and the biofiltration system, including media filter (18 to 22 percent), aggregate (13 to 17 percent), and the underdrain (3 to 11 percent), all of which were sensitive to basin area.

As was the case for the previously discussed projects, the assumption of 250 feet for conveyance between an MS4 outfall and the infiltration basin resulted in a very minor cost (~2 percent of the total cost), while the decision to place excavated material on-site versus hauling it off-site has a much bigger influence on the cost. Additionally, infiltration basin project costs scale with the area of the infiltration basin. The assumption about basin length (i.e. 500 – 2,400 feet) influenced whether the underdrain was a small portion of the cost (3 percent) or a larger portion (11 percent).

The cost per volume ranged from $380 - $138,900 per ac-ft. Using the low-end assumptions, 8 of the 65 sites resulted in costs below the upper limit of existing water supply source costs (Table 2), and with the high-end assumptions, 7 sites fell below the desalination costs. However, use volumes for Alternative B were calculated assuming infiltration rates, not biofiltration rates. It is expected that potential biofiltration volumes would be greater than what was calculated for infiltration, which would mean additional sites could become more economically feasible if these volumes were considered.

2.3 Alternative C, Irrigation Projects

Total cost for irrigation projects ranged from $1,479,100 - $18,747,300. Significant project costs associated with irrigation projects were concrete vault materials and installation costs (60 – 78 percent; this includes excavation) and the irrigation system (9-11 percent). However, when stormwater treatment is required prior to irrigation, the treatment cost represents on average, 20 percent of the total project cost. As was found for other projects, the culvert conveyance from MS4 outfall to the storage vault were minor (0 – 1 percent).

The cost per volume ranged from $38,000 - $638,200 per ac-ft. All projects were above the existing water costs shown in Table 2. The average capture volume was 40 ac-ft/yr, which is greater than infiltration basins and less than injection wells. The high costs for the storage vault, irrigation system, and potential stormwater treatment makes irrigation projects more expensive than other projects, however, possible cost sharing on the irrigation system with the irrigation recipients could reduce costs. Projects within park parcels or close by will be the most economically feasible.

2.4 Alternative D, Rain Barrels

Rain barrels cost $125 before rebates when purchased at Solana Center for Environmental Innovations. Assuming a 0.002 ac-ft/yr volume and a 25-year lifespan, the cost per volume is $2,500 per ac-ft, which is slightly higher than the cost of desalination.

2.5 Alternative E, Restoration and Treatment Wetlands

Total project costs for restoration and treatment wetlands ranged from $185,800 - $1,451,900. The significant costs associated with Alternative E were erosion control and temporary fencing (13 to 19 percent of the total cost), excavation (15 to 20 percent), and the placement of site material (17 to 32 percent), all of which were associated with storage vault footprint size. Like the infiltration basins (Alternative A and Alternative B), there was a strong association between vault acreage and total project costs.

As was the case for the previously discussed projects, the assumption of 250 feet for conveyance between an MS4 outfall and the infiltration basin resulted in a very minor cost (0 – 5 percent of the total cost), while the decision to place excavated material on-site versus hauling it off-site has a much bigger influence on the cost.

The cost per volume ranged from $270 - $2,100 per ac-ft. All but two outlying projects (at $3,300 and $5,200 per ac-ft) of the 27 parcels modeled were lower than existing water supply costs (Table 2). Since restoration requires the least infrastructure, it is the least costly alternative.

2.6 Alternative F, Dry-Weather Flow Diversion to a Wastewater Treatment Plant

Total project costs for dry-weather flow diversion to a wastewater treatment plant range from $2,501,300 - $3,267,000. The highest cost item was the annual sewer fee (64 to 70 percent of the total cost). The other large cost items included excavation (7 to 8 percent of the total cost), placement (0 to 7 percent), and the one-time connection fee (8 to 9 percent). It was assumed that the sanitary sewer system would not need to be upgraded and that current capacity would be sufficient. This assumption may not be reasonable everywhere across the County. Additionally, modeling showed that even during a wet year, discharge from the parcels to the sewer system would still be less than 5 percent volumetrically of the total influent to the receiving plant. Based on this, it was assumed that the treatment plants would not require upgrades to accept stormwater. However, if sanitary sewer upgrade were necessary, the upgrade costs would make this type of project much more expensive.

The cost per volume ranged from $7,400 - $9,600 per ac-ft. Of the 5 modeled parcels, none fall within the range of existing water costs.

2.7 Alternative G-H, Flow Diversion to a Wastewater Treatment Plant

Total project costs for flow diversion to a wastewater treatment plant for recycled water use (Alternative G) and potable water use (Alternative H) ranged from $1,914,300 - $11,732,100. High-cost items included the excavation and placement of the concrete vault (76 to 79 percent of the total cost). Connection to the sewer and the annual sewer fee were around 1 percent of the total cost, which is much lower than under Alternative F, due to the lower annual volume that would be released to the sewer. As discussed above, it was assumed that neither the sewer system nor the treatment plants would require upgrades.

The cost per volume ranged from $12,700 – $388,600 per ac-ft. Of the 5 modeled parcels, all are more expensive than existing water costs.

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ATTACHMENT A

Example Projects

ATTACHMENT B

Example Cost Tables with Assumptions