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memorandum

date	September 20, 2018
to	Stephanie Gaines, County of San Diego
cc	
from	Lindsey Sheehan, PE, David Pohl, PhD, PE, ESA
subject	San Diego Stormwater Capture and Use Feasibility Study – Quantification Analysis and Results (FINAL)

The County of San Diego, in coordination with a Technical Advisory Committee (TAC), is developing the San Diego Stormwater Capture and Use Feasibility Study (SWCFS) through a multi-step process 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:

- Quantifying the range of stormwater that could be potentially captured and stored on public lands and used in the San Diego region;
- Identifying the opportunities and constraints for a range of stormwater capture and use alternatives for use as a management tool in the development and planning of stormwater capture projects and programs; and,
- Prioritizing the potential stormwater use alternatives on a near-, mid-, and long-term timeline basis.

The quantification goal, described in this memo, 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 used as a basis for developing conceptual projects for each alternative in order to model and determine the potential range of stormwater volumes captured and used for selected public parcels. 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 example projects are also provided as a tool for planning and developing similar projects. 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.

The third goal, prioritization of the stormwater use alternatives, is achieved by first evaluating the alternatives based on a set of prioritization criteria, then identifying which alternatives should be considered for near-, mid- or long-term implementation. Alternatives are assessed based on a set of criteria, including the potential regional quantities of stormwater use, described in this memo. Prioritization is also based on the estimated range of cost per volume for each alternative. The type and number of constraints that are "gates" for potential implementation, and the potential opportunities or "keys" to open these "gates", which were developed by the TAC, provide an additional basis for prioritization. The prioritization analysis concludes by identifying regional constraints to implementing stormwater capture and use, with the goal of being a tool to guide the region over time as those constraints are overcome. Overcoming these constraints, or "gates", will allow some near- and potentially mid-term projects and alternatives to move forward toward implementation.

Section 1 of this memo presents an introduction to the conceptual model of stormwater capture and use, as well as a discussion of what makes the San Diego region unique for this study. Section 2 provides the methods used for this modeling effort, Section 3 provides the example projects, and Section 4 presents the results.

1. Background

1.1 Conceptual Model of Stormwater Capture and Use

The SWCFS is based on a framework that considers each step of the stormwater capture and use process. **Figure 1** presents the conceptual model, which starts with stormwater collection and distribution to a retention or storage site/facility. Because stormwater is delivered in variable and sometimes large volumes during a short timeframe, stormwater collection and storage is needed prior to distribution to use. Depending on the stormwater use alternative identified, stormwater may need to be treated, which requires distribution to a treatment system. Lastly, the treated stormwater needs to be distributed to the end user. The following sections provides more detail on this framework.

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Figure 1
Conceptual Model

1.1.1 Collection and Distribution to Storage

Stormwater runoff is generated when the demand for water is lowest, as shown conceptually in **Figure 2** for irrigation. Other potential uses are also characterized by this challenge of matching stormwater delivery with demand for its use. For example, conveyance of stormwater for advanced treatment using existing sanitary sewer lines is constrained during storm events, since increased infiltration to the system results in reduced sewer line capacity. Additionally, subsurface soils may limit the rate of stormwater infiltration to recharge groundwater basins and restore natural hydrology. This challenge of matching stormwater runoff generation with when and at what rate stormwater can be used is addressed through temporary storage or "equalization" of stormwater delivery with use.

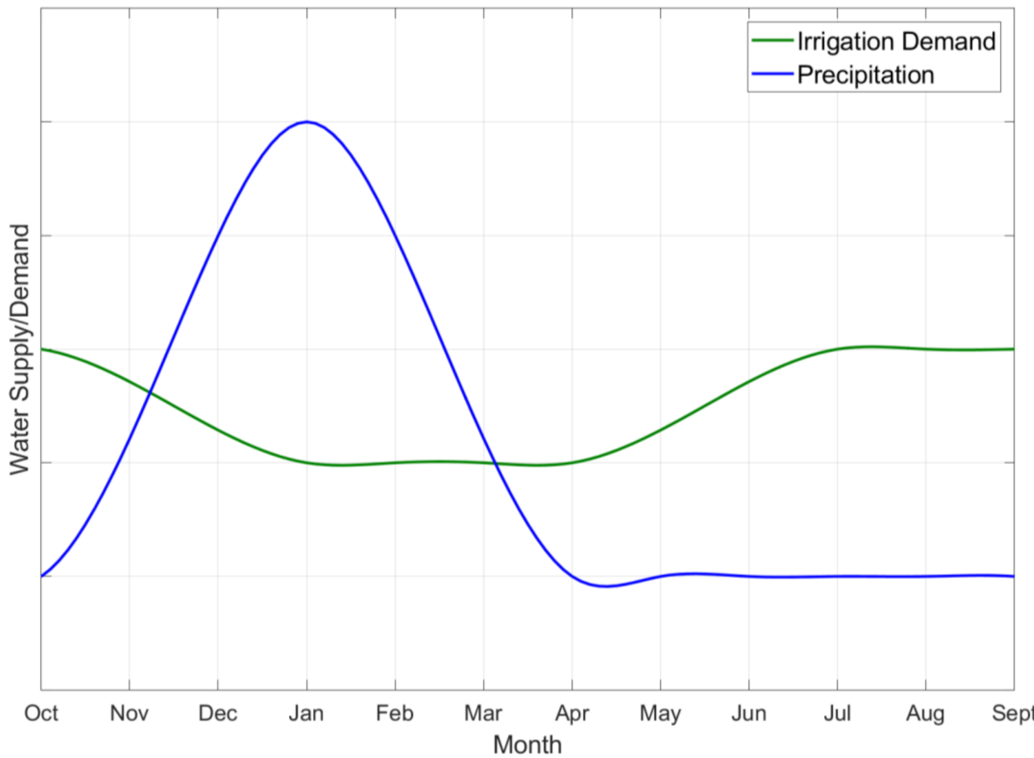

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Figure 2
Conceptual Irrigation Demand and Average Rainfall in Southern California

1.1.2 Retention and Storage

Where to retain and store stormwater is an important element of the conceptual model. The volume of stormwater generated per area is much greater in urbanized areas due to larger areas of impervious surfaces, compared to undeveloped areas (see **Figure 3**). Infrastructure in these urban areas are designed to efficiently direct these larger runoff volumes to storm drain systems to address potential flooding and public safety concerns. Storage of stormwater in these urbanized areas is often limited; however, current new- and re-development regulations encourage the use of low impact development (LID) (see **Figure 4**) to increase retention time of stormwater and allow for filtration and infiltration to reduce the impacts of pollutants and peak flows on receiving waters. These approaches provide opportunities for greater storage.

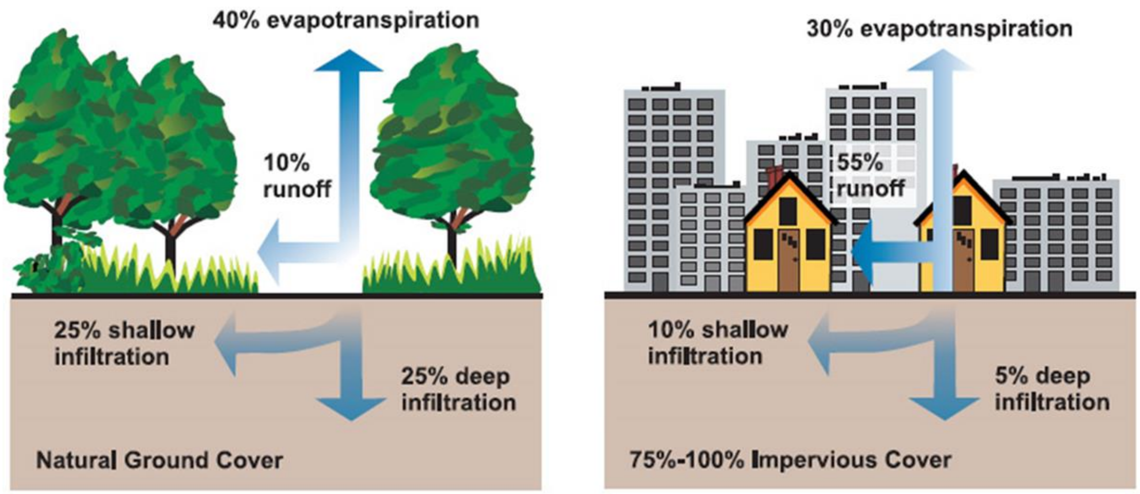

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Figure 3
Runoff as a Percentage of Rainfall
Undeveloped vs. Urban

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Figure 4
Example of LID

1.1.3 Identification of Stormwater Use Alternatives

The third component of the conceptual model is the identification of potential stormwater use alternatives. Eight alternatives have been identified for the region as end uses for stormwater that is captured, and include hydrologic recharge, recycled or potable use, or stormwater treatment. The stormwater use alternatives that will be evaluated for the San Diego region are presented in more detail in Section 2.1.

1.1.4 Treatment for Stormwater Use

Urban stormwater runoff collects and transports numerous pollutants from roadways, landscaped areas, and various commercial, industrial, and residential land uses and activities. These constituents include indicator bacteria, metals, pesticides, sediment, nutrients and trash, among others[1]. Treatment to address these constituents would be required prior to some uses, depending on the end use and established water quality standards, treatment facility requirements, and quality of the stormwater captured.

1.1.5 Distribution to End User

The final distribution of stormwater to the end user would depend on the use alternative (or alternatives, for multiple benefits) chosen. This could be directing the stored stormwater to a groundwater basin, to a pre-treatment facility prior to use on-site for irrigation or for groundwater recharge, or to a sanitary sewer line for advanced treatment and then distribution for recycled water, groundwater injection or further treatment for potable use.

1.2 San Diego Regional Setting

The San Diego region is unique when compared to many other areas in the state in its geology, topography, and micro-climates. The San Diego region has been successful in capturing stormwater in the upper portions of the watershed near the inland mountains where higher rainfalls are captured and stored in reservoirs used for water supply. This system of reservoirs and treatment facilities is shown in **Figure 5**. The volume of stormwater captured in reservoirs represents a limited amount of the total stormwater that could be captured and used.

San Diego County is dominated by canyon lands with developed mesas that drain to often steep sloped and narrow canyons. Soils in the region are predominately low permeability clays and silts. Isolated groundwater basins are found along the larger river systems and in several inland valleys. The opportunity for direct infiltration to groundwater basis is therefore limited in this region compared to Los Angeles, which has a large groundwater basin with higher permeable soils that extend to coastal urbanized areas. In San Diego, more urbanized areas dominate the coastal areas where a high percentage of the developed land is impervious and urban runoff is directed to the Municipal Separate Storm Sewer System (MS4) to address flood risk and potential property damage and public safety, and directed to flood channels that discharge to estuaries and the ocean.

Because of the geographic distribution of the system of reservoirs in the region, the opportunity for future stormwater capture for one or more of the use alternatives is likely to come from the more-urbanized, western portions of the watersheds, where capture and use is not already implemented effectively. In addition, urban areas have a larger runoff percentage for a given rainfall area (Figure 3), and multiple benefits can be achieved by addressing water quality, flood risk, and community and environmental benefits. New and redevelopment along with targeted retro-fits (e.g. green streets) are using low impact development that increase the retention and infiltration, where possible, in these urban areas to improve water quality, decrease flood risk, and increase subsurface infiltration to restore natural hydrology.

[1] The Clean Water Act Section 303(d) list is available at https://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml

While this study focuses on existing public parcels, recent and planned expansion of existing reservoirs may offer an opportunity to move storage capacity between reservoirs, providing the potential for greater stormwater collection and storage in existing reservoirs close to urban areas.

1.3 San Diego Region Stormwater Resource Plan

This assessment builds on the preliminary quantification of potential stormwater capture that was assessed in the SWRP (ESA, 2017a). Potential storage sites were first identified in the SWRP using Geographic Information System (GIS) data for public parcels within the San Diego County region that were designated as open space, park, or vacant, and were at least an acre in size. These public parcels were then assessed for potential stormwater use alternatives that included direct infiltration, storage and off-site use for irrigation, and storage and diversion to a treatment facility for recycled or indirect potable water. The volume estimates were based on a limited number of "conceptual" alternative use project layouts that were then used to project volumes for other parcels. These preliminary estimates did not consider specific site and use constraints for the treatment use alternative, such as location and capacity of existing conveyance lines and treatment facilities. The resulting preliminary *conceptual* total stormwater use potential was approximately 92,000 acre-feet per year (ac-ft/yr). For reference, the San Diego region's annual potable water demand is on the order of 450,000 ac-ft/yr, so this *conceptual* estimate represented about 20% of total regional demand. This preliminary estimate (Steps 1 and 2 in **Figure 6**) is refined as part of the quantification modeling performed for this feasibility study and the results are presented in the following sections.

1.4 San Diego Region Stormwater Capture and Use Feasibility Study

The analysis methodology for this SWCFS is based on the six components of the conceptual model in Figure 1. As presented in Figure 6**,** the SWCFS approach consists of eight steps. The potential public storage sites analysis from the SWRP (Steps 1 and 2) was refined using screening criteria to determine applicability and feasibility for a greater number of potential stormwater use alternatives. Regional quantities of potential stormwater capture and use are also refined using a significantly larger set of sites for hydrology modeling of storage capacity and conceptual use. Example stormwater capture and use projects are also identified and assessed in this SWCFS and provide guidance to managers developing, planning, and designing these projects.

As part of the next step and in future memos, the use alternatives will be prioritized based on a set of criteria, including total potential regional volume captured and used, cost per volume, constraints and opportunities, and potential multi-benefits.

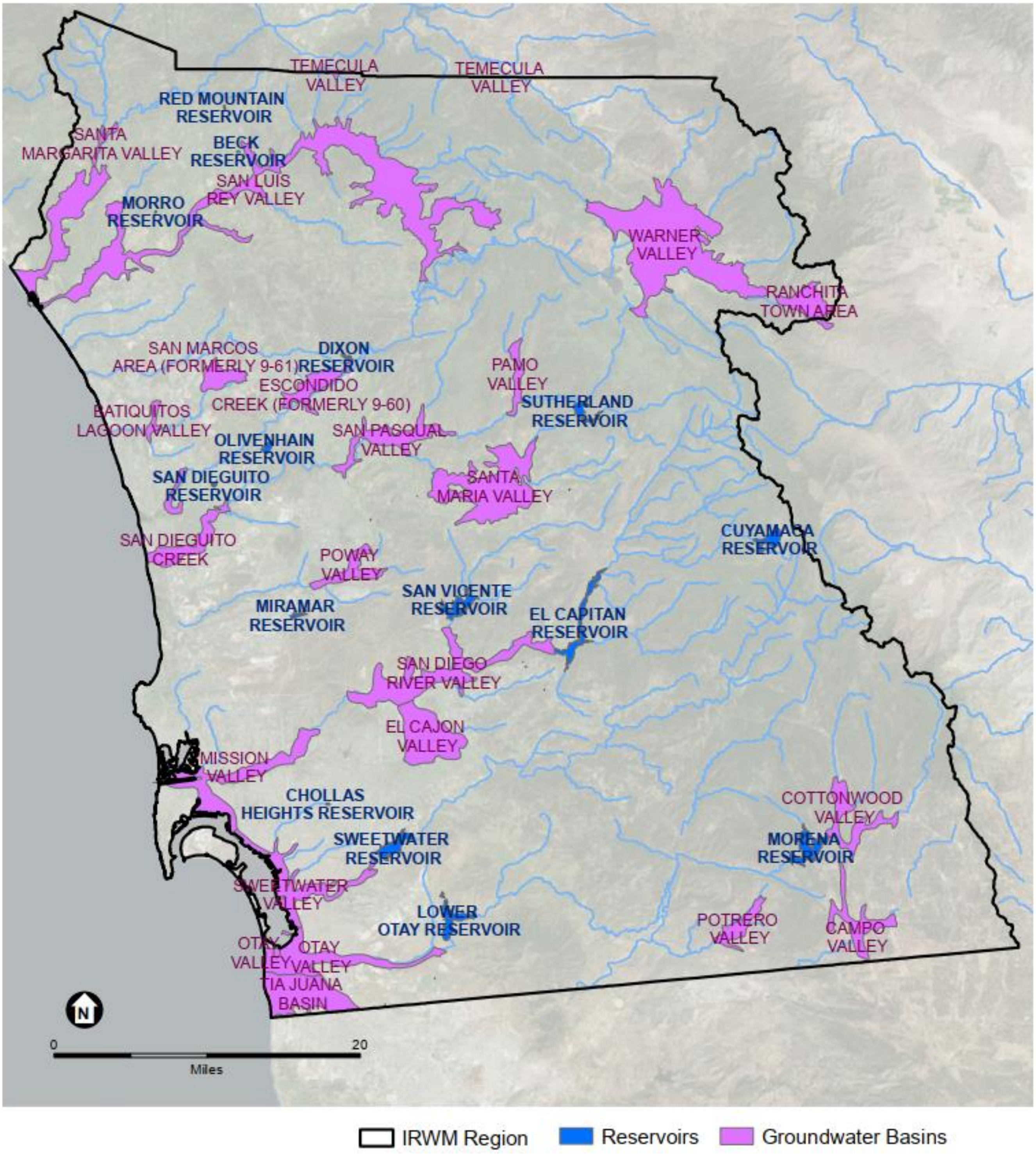

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Figure 5
Surface Water Reservoirs and Groundwater Basins in the San Diego Region

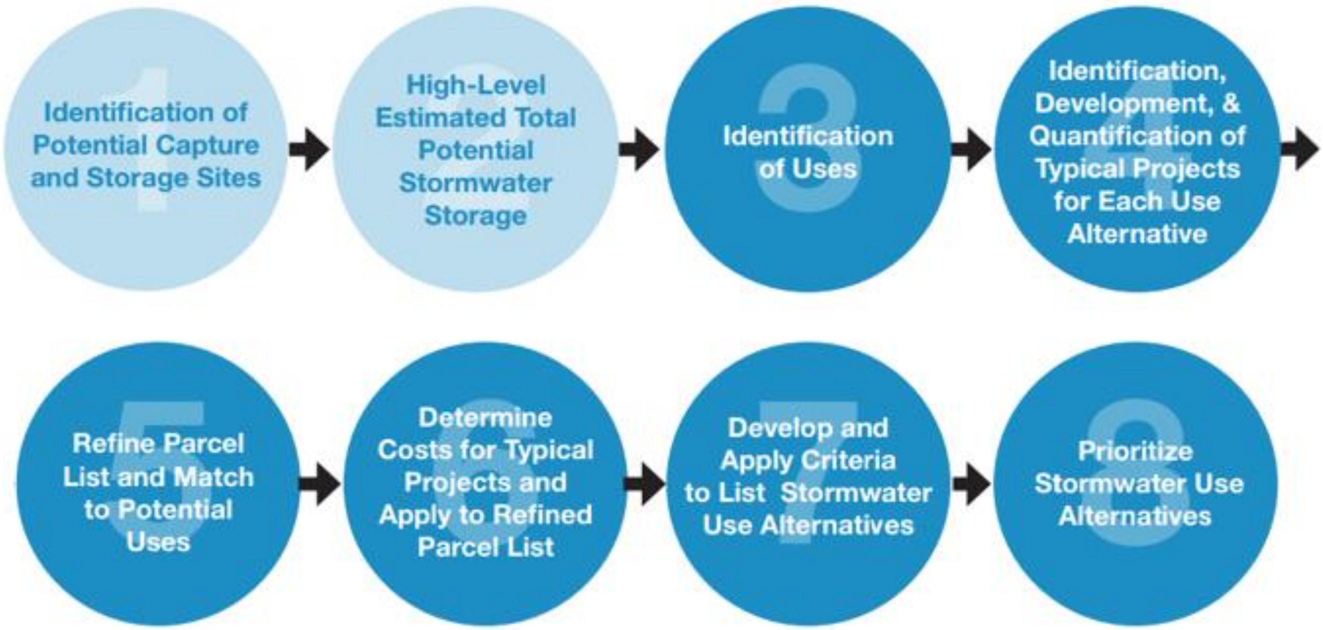

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Figure 6
Model Approach

2. Methods

Using the model approach presented in Figure 6, the methods for the SWCFS are presented below. Note that Steps 1 and 2 were completed as part of the San Diego Region SWRP. Step 6 will be documented in a separate cost analysis memo and Steps 7 and 8 will be documented in a prioritization analysis memo.

2.1 Step 3. Identification of Stormwater Use Alternatives

As presented in **Figure 7**, eight stormwater use alternatives have been identified for captured stormwater in the San Diego region (Step 3 in Figure 6). These alternatives have been developed based on the review of existing plans developed in the region and in Southern California. Opportunities and constraints associated with each stormwater use alternative were discussed at the TAC #2 meeting and the discussion from that meeting has been incorporated in this report.

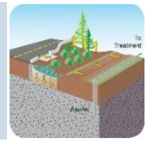
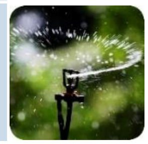
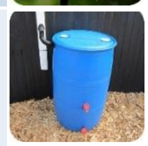
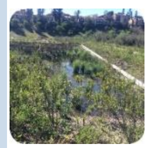
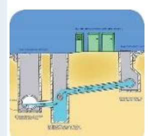
	Eight Stormwater Use Alternatives	
A	Direct discharge to designated groundwater basins to be extracted for potable use	
B	Discharge to groundwater to reestablish natural hydrology and, by extension, to restore biological uses	
C	Irrigation to be used on-site or at nearby parks, golf courses, or recreational areas on public parcels	
D	Small scale on-site use for irrigation and other private use on private parcels	
E	Flow-through to sustain vegetation in natural treatment system (wetland treatment) and/or restoration sites	
F	Dry weather flow diversion to wastewater treatment plants for solids management	
G	Controlled discharge to waste water treatment plants for indirect potable use	
H	Controlled discharge to waste water treatment plants for recycled water use	

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Figure 7
Stormwater Use Alternatives

2.2 Step 4. Identification, Development, and Quantification of Typical Projects for Each Use Alternative

Based on the stormwater use alternatives presented in Figure 7, conceptual projects were developed for each alternative based in part on the example projects. The assumptions used to quantify these typical projects are presented in the results in Section 3.2.

2.3 Step 5. Refine Parcel List and Match to Potential Stormwater Use Alternatives

The fifth step in the approach is to refine the list of public parcels generated in Step 1 through the application of feasibility screening criteria from the constraints identified by the TAC at the second workshop. Screening criteria are applied to the 12,731 public parcels for each of the stormwater use alternatives. The outcome of this step is a refined list of feasible parcels for each alternative that can then be used to quantify the regional potential stormwater use for each alternative. Parcels may have one or more alternatives depending on the outcome of the screening. Feasibility screening criteria are informed by the constraints identified by the TAC in the second workshop. **Table 1** provides a summary of the feasibility screening criteria applied to the public parcels for each of the eight stormwater use alternatives.

TABLE 1
PUBLIC PARCEL FEASIBILITY SCREENING CRITERIA

Stormwater Use Alternative	Screening Criteria Applied to the Public Parcels	Basis for Criteria
Applied to all parcels	Greater than 1 acre	Sufficient area for storage
	Portion of the site less than a 15% slope	Maximum slope feasible to create storage without significant and costly site grading
Alternative A (Discharge to Groundwater for Potable Use)	Major (36-inch diameter) MS4 outfall located within the parcel	Need for sufficient source of stormwater parcel
	Soil infiltration grade of A, A/D, B, or C	Infiltration rates needs to be sufficient to balance storage
	Within a mile of a groundwater basin that is used for potable water supply.	Needs to be near where use is designated
Alternative B (Discharge to Groundwater for Natural Hydrology)	Major (36-inch diameter) MS4 outfall located within the parcel	Need for sufficient source of stormwater at parcel
Alternative C (Irrigation)	Major (36-inch diameter) MS4 outfall located within the parcel	Need for sufficient source of stormwater at parcel
	Within a quarter mile of a park, golf course, or recreational area	Needs to be near where stormwater can be used to augment irrigation
Alternative E (Restoration and wetland treatment)	Major (36-inch diameter) MS4 outfall located within the parcel	Need for sufficient source of stormwater at parcel
	Within 200 feet of an estuary or waterway OR Within a quarter mile of a park, golf course, or recreational area	Needs to be near where flows from the MS4 can be used for restoration or treatment wetlands
Alternative F-H (Diversion to WWTP)	Within 200 feet of sewer lines for a feasible WWTP	Proximity to existing sanitary sewer line for diversion to a WWTP that has current or near-term capacity

Using a GIS analysis, these feasibility criteria are used to screen the potential parcels and develop a list of feasible parcels for each of the stormwater use alternatives. The goal of this analysis is to evaluate stormwater capture and use potential at a high-level, region-wide. The goal is not to eliminate parcels, but to identify parcels that are most feasible for the alternative uses. Managers will need to evaluate parcels on a project-level to determine whether a parcel should be eliminated or selected for a stormwater capture and use project.

3. Refined Parcel List and Quantification Results

This section describes the refined parcel and quantification analysis and the resulting preliminary regional estimated ranges in volumes for each use alternative. Once the refined parcel list was developed (Section 3.1), a subset of those parcels was modeled using the San Diego Hydrology Model (SDHM) 3.1 to determine the volume and timing of stormwater that enters each site over a 40-45-year historic rainfall record (Section 3.2.1). Then, depending on the stormwater use alternative, the volume that could be stored and used over the course of those 40-45 years was determined and an average annual volume was calculated (Section 3.2.2). Lastly, the analysis of the subset of parcels was utilized to extrapolate potential capture volume and use to all of the remaining identified, but unmodeled parcels (Section 3.2.3).

Alternative D, irrigation for private use, was analyzed separately from the parcel assessment as described in Section 3.2.2.4.

3.1 Refined Parcel Analysis

Public parcels were screened using the feasibility screening criteria for each stormwater use alternative presented in Table 1 (Section 2.2). **Table 2** presents the number of parcels initially identified using these feasibility criteria and the selected sub-set of these screened parcels that were modeled in Section 3.2. For this feasibility-level analysis a subset of parcels was identified for modeling based on data availability.

Table 2 also includes the feasibility criteria used to screen the parcels and the number of parcels that were screened out at each step. The lower rows of the table provide the screening criteria used in the SWRP analysis for comparison. For the SWRP, only infiltration to a groundwater basin (Alternative A) and irrigation (Alternative C) were considered for the parcel analysis. The refined analysis shows a very similar number of parcels to the SWRP for irrigation, but shows considerably fewer parcels for infiltration. This is due to the added criteria that a parcel be near an MS4 outlet sized 36 in or greater and that the site soils must be hydrologic soil type A, B, or C (not D).

TABLE 2
REFINED PARCEL ANALYSIS RESULTS

	Feasibility Screening Criteria							
Stormwater use alternative	**# of Public Parcels < 1 ac or no area <15 % slope**	**Location**	**Poor Soil Infiltration**	**No MS4 or MS4 <36"**	**No Current Plant Capacity**	**Infeasible Parcel (in a waterway, etc.)**	**Total # of Parcels Analyzed**	**# of Parcels Modeled**
A – Infiltration to Groundwater Basin	2,395	-60[1]	-2,244	-51	n/a	-11	29	17
A – Injection to Groundwater Basin	2,395	-1,645[2]	n/a	-727	n/a	-14	9	9
B – Infiltration for Hydrology	2,395	n/a	n/a	-2,276	n/a	-31	88	66
C – Irrigation	2,395	-1,516[3]	n/a	-786	n/a	-32	61	51
E – Use for Treatment Wetland	2,395	-851[4]	n/a	-1,431	n/a	-13	100	44
F-H – Wastewater Treatment	2,395	-1,207[5]	n/a	n/a	-1,063	-2	123	6 (57)[6]
Total Uses							**410**	**177**
Total Parcels[7]							**211**	**67**

SWRP Analysis	**# of Public Parcels < 1 ac or no area <15 % slope**	**Location**	**Poor Soil Infiltration**	**No MS4 or MS4 <36"**	**No Current Plant Capacity**	**Infeasible Parcel (based on land use)**	**Total # of Parcels Analyzed**	**# of Parcels Modeled**
A – Infiltration to Groundwater Basin	2,395	-601	n/a	n/a	n/a	-1,215	1,120	n/a
C – Irrigation	2,395	-1,516[2]	n/a	-786	n/a	-6	87	n/a
Total Parcels							**1,207**	**5**

1. Sites not within 1 mile of a groundwater basin
2. Sites not directly above a groundwater basin
3. Sites not within ¼ mile of a park, recreation area, or golf course
4. Sites not within 200 ft of a waterway or lagoon OR within ¼ mile of a park, recreation area, or golf course
5. Sites not within 200 ft of a sewer line
6. Six sites of the 123 near plants with sufficient capacity were modeled, but a total of 57 sites throughout the region near other WWTPs were modeled as well, to evaluate potential capture and use pending expanded WWTP capacity.
7. Some parcels have multiple uses available.

3.2 Stormwater Capture and Use Regional Quantification

3.2.1 Hydrologic Modeling

For each parcel in the subset, the potential drainage area was determined based on a GIS analysis using topographic and MS4 data for the site. Additional data for each MS4 outfall drainage area were gathered to determine land use (defining permeability and friction), slope, and soil type. The SDHM3.1 was then used to model runoff volume and timing to each site based on 40 to 45 years of historic rainfall data from the nearest San Diego ALERT station. The model outputs an hourly time series of flow at the parcel over the 40- to 45-year period.

3.2.2 Stormwater Use Alternative Analysis

Using the time series from the hydrologic modeling, the possible volume that could be used at each site was determined. The following sections describe this analysis for each stormwater use alternative.

3.2.2.1 Alternative A, Infiltration to a Groundwater Basin

Two methods to infiltrate stormwater to a groundwater basin were considered in this analysis: infiltration through an above ground basin, and injection through a well.

Infiltration Basin

Infiltration basins were sized for each parcel based on the available land near an MS4 outfall. A basin depth of 3 ft was assumed using best professional judgement. Additionally, each basin was assumed to have a downstream drain that would drain at a rate that would ensure that standing water does not exceed the 72-hour threshold for vector control, based on infiltration rates per soil type (**Table 3**). For example, a 50,000 square foot (sf) basin could store 150,000 cubic feet (cf) of stormwater (assuming a 3-foot depth) at its maximum. Assuming a soil type of A/B with an infiltration rate of 0.30 in/hr, the basin could infiltrate 21.6 in or 90,000 cf of stormwater in 72 hours. The remaining 60,000 cf of water would need to be drained through the outfall over the 72 hours, so it would require a drainage rate of 830 cf per hour.

TABLE 3
INFILTRATION RATES BY SOIL TYPE

Hydrologic Soil Type	Infiltration Rate (in/hr)
A	0.30 – 0.50
B	0.15 – 0.30
C	0.05 – 0.15
D	0 – 0.15

Using the basin designs and infiltration rates, the volume of stormwater runoff in the basin, the volume infiltrated, and the volume drained were determined for each time step. For the same example basin described above, if a storm event creates a constant flow rate of 4 cubic feet per second (cfs), the basin would have 14,400 cf in it after an hour, or a depth of 3.5 in (0.3 ft). In the next hour, another 3.5 in would be added to the basin, but 0.3 in would be infiltrated and 830 cf or 0.2 in would be drained, for a total storage depth of 6.5 in remaining. If the storm ended at this point, the next hourly time steps would infiltrate another 0.3 in and drain 0.2 in until the basin was empty. This example is shown in **Table 4**. The analysis is then repeated for the full 40- to 45-year time series and the infiltrated volume is averaged per year.

TABLE 4
EXAMPLE INFILTRATION CALCULATION

Time step (hour)	Runoff to Parcel (cfs)	Water Depth in Basin (in)	Runoff Depth (in)	Infiltrated (in)	Drained (in)
1	4 (storm begins)	0 (basin empty)	+3.5	0	0
2	4	3.5	+3.5	-0.3	-0.2
3	0 (storm ends)	6.5	0	-0.3	-0.2
4	0	6.0	0	-0.3	-0.2
5	0	5.5	0	-0.3	-0.2
6	0	5.0	0	-0.3	-0.2
7	0	4.5	0	-0.3	-0.2
8	0	4.0	0	-0.3	-0.2
9	0	3.5	0	-0.3	-0.2
10	0	3.0	0	-0.3	-0.2
11	0	2.5	0	-0.3	-0.2
12	0	2.0	0	-0.3	-0.2
13	0	1.5	0	-0.3	-0.2
14	0	1.0	0	-0.3	-0.2
15	0	0.5	0	-0.3	-0.2
16	0	0 (basin empty)	0	0	0
	Total Depth			**4.2 in**	**2.8 in**
	Total Volume			**17,500 cf**	**11,700 cf**

The parcel analysis results found that infiltration basins ranged from 0.4 to 58.8 acres (15,700 to 2,560,900 square feet (sf)) with annual average infiltration volumes of 0.03 to 78.5 ac-ft/yr (1,300 to 3,419,500 cf/yr) for each parcel.

Injection Wells

To use injection wells, it was assumed that an underground vault would be required to store stormwater before it is injected. The vaults were sized for each parcel based on the available land (e.g. open space, parking) near an MS4 outfall. A vault depth of 6 ft was assumed based on best professional judgement.

Injection rates vary depending on hydraulic conductivity of a groundwater basin, aquifer thickness and area, whether the basin is confined or unconfined, depth to water table, and density of injection wells. Injection rates were determined for each parcel based on the California Department of Water Resources Bulletin 118 Groundwater Basins (1975), with the assumption that injection rates per well would be equal to the average withdrawal rate of production wells reported in Bulletin 118 for the basin. Injection rates varied from 250 – 600 gallons per minute or 0.56 – 1.34 cfs per well. It was conservatively assumed that each basin would have one injection well.

Using the vault designs and injection rates, the volume in the vault and the volume injected were determined for each time step. For example, consider a 50,000 sf vault with a storage volume of 300,000 cf. If a storm event creates a constant inflow rate of 5 cfs, the vault would have 18,000 cf in it after an hour. Assuming the injection well turns on after 5% of the volume in the vault is reached, or 18,000 cf, in the next hour, 2,412 cf would be injected (rate of 0.67 cfs) while another 18,000 cf is added to the vault for a total volume of 33,588 cf. If the storm ended at this point, the next time steps would inject another 2,412 cf until the basin is empty. This example is shown in **Table 5**. The analysis is then repeated for the full 40- to 45-year time series and the injected volume is averaged per year.

TABLE 5
EXAMPLE INJECTION CALCULATION

Time step (hour)	Runoff to Parcel (cfs)	Water Volume in Basin (cf)	Runoff Volume (cf)	Injected (cf)
1	5 (storm begins)	0 (basin empty)	+18,000	0
2	5	18,000	+18,000	0 (pump turns on)
3	0 (storm ends)	33,588	0	-2,412
4	0	31,176	0	-2,412
5	0	28,764	0	-2,412
6	0	26,352	0	-2,412
7	0	23,940	0	-2,412
8	0	21,528	0	-2,412
9	0	19,116	0	-2,412
10	0	16,704	0	-2,412
11	0	14,292	0	-2,412
12	0	11,880	0	-2,412
13	0	9,468	0	-2,412
14	0	7,056	0	-2,412
15	0	4,644	0	-2,412
16	0	2,232	0	-2,232
17	0	0 (basin empty)	0	0
	Total Volume			**36,000**

The results found that injection wells produced annual average infiltration volumes of 1.4 to 140.4 ac-ft/yr (60,980 to 6,115,810 cf/yr). The average injection well produced just over four times more than the average infiltration basin.

3.2.2.2 Alternative B, Infiltration for Hydrology

Infiltration basins for Alternative B were sized the same as for Alternative A. Similarly, the infiltrated volume was calculated the same as described above. The difference between the two alternatives comes through the parcel analysis where parcels for Alternative A are required to be above a groundwater basin used for potable use, which is not a requirement for Alternative B.

The results found that infiltration basins have annual average infiltration volumes of 0.03 to 78.5 ac-ft/yr (1,300 to 3,419,500 cf/yr).

The analysis was limited to public parcels where above and below ground infiltration basins could be implemented. The analysis for Alternative B did not include the assessment of infiltration from green street projects, which could be retro-fitted along existing streets. The available data on the specific location and extent of planned green streets on available right-of-ways and existing streets is limited. For this analysis, streets and right-of-ways were not considered. These opportunities are extensive and were considered in the sensitivity analysis as discussed later in this memorandum.

3.2.2.3 Alternative C, Irrigation

Stormwater collection for irrigation was analyzed using underground vaults sized for each parcel based on the available land near an MS4 outfall and with an assumed depth of 6 ft based on best professional judgement.

Average irrigation rates were calculated based on Estimated Total Water Use (ETWU), measured in gallons per year, in different regions of the county (coastal, inland, mountain, and desert). These annual values were divided over the average number of dry days in the San Diego region, yielding estimated daily use on dry days, which was converted to an irrigation rate in cfs. All parcels fell within the coastal and inland regions, which had the same irrigation rate of 0.004 cfs per acre.

Using the vault designs and irrigation rates, the volume in the vault and the volume used for irrigation were determined for each time step. This analysis is identical to the one described for injection wells, except using the calculated irrigation rate rather than the injection rate. Considering the same example as in Section 3.2.2.2 (50,000 sf vault, with a constant storm flow rate of 5 cfs), **Table 6** presents an example of the model calculation assuming an irrigation rate of 0.004 cfs per acre for a 130-acre golf course.

The results found that the identified parcels could produce an annual average irrigation volume of 0.002 to 38.2 ac-ft/yr (90 to 1,663,990 cf/yr). At the low end of the range, irrigation was limited by park size (i.e. irrigation need).

TABLE 6
EXAMPLE IRRIGATION CALCULATION

Time step (hour)	Runoff to Parcel (cfs)	Water Volume in Basin (cf)	Runoff Volume (cf)	Used for irrigation (cf)
1	5 (storm begins)	0 (basin empty)	+18,000	0
2	5	18,000	+18,000	0
3	0 (storm ends)	36,000	0	0
4	0	36,000	0	0
74 (3 days later)	0	36,000	0	-1,872
75	0	34,128	0	-1,872
76	0	32,256	0	-1,872
77	0	30,384	0	-1,872
78	0	28,512	0	-1,872
79	0	26,640	0	-1,872
80	0	24,768	0	-1,872
81	0	22,896	0	-1,872
82	5 (new storm begins)	21,024	+18,000	0
83	0 (storm ends)	39,024	0	0
84	0	39,024	0	0
154 (3 days later)	0	39,024	0	-1,872
155	0	37,152	0	-1,872
174	0	1,584	0	-1,584
175	0	0 (basin empty)	0	0
	Total Volume			**54,000 cf**

3.2.2.4 Alternative D, Irrigation for Private Use

Although there are many opportunities for stormwater capture and use on private properties, quantifying the potential regional stormwater volume that could be used is difficult given the private ownership of these properties. Larger scale stormwater capture and use projects have applicability to new and re-developed commercial properties and larger residential developments, which also are required to meet stormwater quality and hydromodification requirements. Stormwater capture and use projects at these sites may be sized larger than the design capture volume and provide for alternative compliance credits for other development and re-development projects. Due to limited data and land ownership/control, this study focuses on estimated quantities on public lands. Data is available on the capture of stormwater and use for irrigation using rain barrels on residential parcels, and an analysis of these data was conducted for this study. Additionally, a study is currently being conducted by students at San Diego State University to assess the stormwater capture and use potential for industrial sites.

The volume of stormwater that could potentially be collected and used in a 50-gallon rain barrel annually was roughly calculated. Existing data shows that roughly a quarter of purchases for rain barrels was for only one rain barrel (as opposed to multiple barrels). In this study, rain barrels were assumed to be independent from one another to estimate the maximum stormwater volume that may be captured. Using an average roof surface area of 2,500 sf and the 40-45-year rain time series from the SDHM3.1, an analysis similar to the one described for irrigation in Section 3.2.2.3 was conducted. It was assumed that each parcel had 1,250 sf of garden or lawn to irrigate and the same irrigation rate of 0.004 cfs per acre was used.

The results found that one rain barrel could produce an annual average irrigation volume of 0.002 ac-ft/yr. The volume is smaller than the other alternatives due to the smaller storage volume.

3.2.2.5 Alternative E, Use for Treatment Wetland

Underground vaults were sized for each parcel based on the available land near an MS4 outfall. A vault depth of 6 ft was assumed based on based on best professional judgement.

Because wetland restorations or treatment wetlands use dry weather flows to sustain the wetland, dry weather flows were estimated for each parcel. Measured dry weather flows in the region showed that roughly a quarter of monitored sites received dry weather runoff (Wood PLC 2017). Assuming that sites with the largest drainage areas would have the most dry weather flow, the 25% of parcels with the largest drainage areas were identified. An average flow rate was determined from the runoff data and applied at each site.

Using the vault designs, dry weather flows, and an assumed wetland irrigation rate of 1 cfs, the volume in the vault and the volume used for irrigation were determined for each time step. This analysis is identical to the one described for irrigation, except using 1 cfs for the irrigation rate and using dry weather flows instead of storm flows. See the example in Section 3.2.2.3.

The results found that the identified parcels could produce an annual average flow through volume of 27.1 ac-ft/yr.

3.2.2.6 Alternative F, Dry Weather Diversion to Wastewater Treatment Plant for Solids Management

Underground vaults were sized for each parcel based on the available land near an MS4 outfall. A vault depth of 6 ft was assumed based on best professional judgement.

Sewer system capacity for each major sewer segment was determined in the two sewersheds that were evaluated based on available data on treatment plant capacity, for flow augmentation to a downstream WWTP (Padre Dam and South Bay Water Reclamation Plant (SBWRP)). Each sewershed was evaluated separately. The evaluation was performed to determine whether each major sewer segment (“major” being defined as 24-in diameter or greater for the SBWRP sewershed and at least 21-in or greater for the Padre Dam sewershed) has capacity to meet flows from parcel discharge, in addition to its base wastewater flows. Useable storage parcels from the parcel analysis were only assigned once to a given sewer in the system evaluation. Base wastewater flows for a given gravity sewer segment were primarily calculated assuming the pipe flows at 50% full and at 8 feet per second (fps) during low flow conditions, when parcel discharge would be utilized. The estimated discharge flow from each adjacent parcel and from each parcel upstream from a given gravity sewer segment were added. The relative flow depth, or percent full (d/D where d=flow depth and D=pipe diameter) was calculated. For gravity sewers where this value was found to be 75% or less, it was assumed capacity exists to accept parcel discharge. For force main lines, the base wastewater flow was calculated by adding the base wastewater flow from all upstream gravity sewer branches that feed the force main. Flow from all upstream parcels and any parcels adjacent to a given force main were added to this base wastewater flow. Assuming force mains flow at 100% full, the flow velocity was calculated. Force main lines that yielded a flow velocity of 8 fps or under were assumed to have capacity to accept parcel discharge.

Each major sewer segment in each of the two sewersheds was analyzed for capacity following this approach. The evaluation varied the assumed discharge flow per parcel, to determine the maximum discharge flow at which the majority of each sewershed would run at or under capacity. With the exception of a few "bottleneck" locations in each sewershed, where gravity sewer size was seen to decrease substantially, the majority of pipes in both sewersheds were within capacity when parcel discharge flow was maintained at 0.5 cfs.

As was assumed for Alternative E, the 25% of parcels with the largest drainage areas were identified and an average dry weather flow rate was determined from the runoff data and applied at each site. Using the vault designs and dry weather flows, and an assumed discharge rate of 0.5 cfs, the volume in the vault and the dry weather diversion volume were determined for each time step. The results found that the identified parcels could produce an annual average irrigation volume of 13.6 ac-ft/yr.

3.2.2.7 Alternatives G-H, Wastewater Treatment

Using the analysis of the storm sewer system described for Alternative F in Section 3.2.2.6 above, a maximum discharge rate of 0.5 cfs was assumed. Underground vaults were sized for each parcel based on the available land near an MS4 outfall. A vault depth of 6 ft was assumed based on best professional judgement.

Next, using the vault designs and maximum discharge rate, the volume in the vault and the volume discharged were determined for each time step after a storm. This analysis is identical to the one described for irrigation, except using the discharge rate of 0.5 cfs rather than the irrigation rate. See the example in Section 3.2.2.3.

The results found that the identified parcels could produce an annual average volume of 0.03 to 37.7 ac-ft/yr (1,310 to 1,642,210 cf/yr) to divert to the two evaluated WWTPs for which data on the system capacity was available.

3.2.3 Regional Extrapolation

3.2.3.1 Alternatives A-C and E-H – Parcel Extrapolation

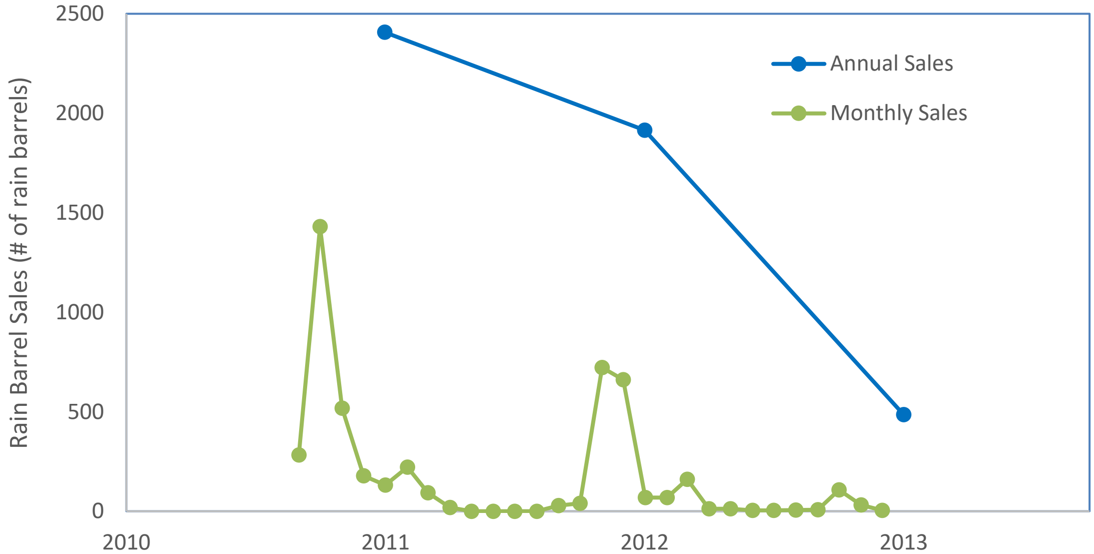
In the results for Alternatives A, B, and C, the MS4 drainage area was found to be the best predictor of annual infiltrated volume for each parcel. An equation was developed to predict infiltration based on drainage area. For parcels where the drainage area was not delineated, an average of 6.3 ac-ft/yr was assumed for Alternatives A and B and 4.4 ac-ft/yr was assumed for Alternative C.

For Alternatives E and F an average of 27.1 and 13.6 ac-ft/yr was used, respectively, for all unmodeled parcels. For Alternatives G-H an average of 6.5 ac-ft/yr was used.

3.2.3.2 Alternative D – Rain Barrel Sales Projection

Rain barrel sales data for late 2015 through 2017 were collected from Solana Center for Environmental Innovation (SCEI), which sells rain barrels for the County of San Diego (**Figure 8**). The data show that rain barrel purchases over the last three years have decreased, likely due to a number of conditions: first, decreases in rebates have made rain barrels more expensive to the customer; second, drought conditions increased awareness around conservation, while heavy rains in 2016-2017 may have inspired sales previously. When conditions are right (i.e. cost, promotion, and weather) sales are around 2,500 rain barrels per year. When conditions are not favorable, sales are around 500 rain barrels per year.

The size of rebates from the Metropolitan Water District of Southern California, which have decreased over the last few years, seem to have significant impact on sales. There may also be an opportunity for jurisdictions to improve sales by subsidizing the sales program, or funding advertising, promotion, and other marketing strategies. Assuming a maximum market penetration of 10% of the 1,103,128 households in San Diego (United States Census Bureau 2017), 105,500 barrels could potentially still be sold.



SOURCE: Historic date from SCEI

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Figure 8
Projected Rain Barrel Sales

Using the high and low estimates (i.e. ideal and less favorable conditions) for the next ten years as the minimum and maximum opportunity for rain barrel sales, along with the annual rain barrel capture volume, an estimate of the potential stormwater that can be captured can be calculated. The total additional volume that could be captured ranges from 10 to 50 ac-ft/yr, as shown in **Table 7**.

TABLE 7
TOTAL RAIN BARREL STORMWATER CAPTURE VOLUME

	Number of Rain Barrels Sold	Volume of Stormwater Captured and Used (ac-ft/yr)
Currently in Use	4,808	9.6
Minimum Projection	+5,000 (in next 10 years)	10
Maximum Projection	+25,000 (in next 10 years)	50

3.2.3.3 Sensitivity Analysis

Parcel Analysis

For Alternative A, the soils screening criteria is also very restrictive to the number of parcels considered in the analysis, since a majority of soils in the San Diego region have soil type D with low permeability. However, injection wells would penetrate deep enough to potentially not be subject to soil permeability constraints, making additional parcels feasible. This means injection wells could potentially increase the feasibility of infiltration to groundwater basins by 223 parcels assuming any size MS4 outfall within 250 ft of a parcel, but requiring parcels to be directly above a groundwater basin (and not just within one quarter mile). However, this is an overestimate, since site feasibility depends on hydraulic conductivity of a groundwater basin, aquifer thickness and area, whether the basin is confined or unconfined, and depth to water table, none of which have been evaluated for these additional parcels. Since only half of the parcels modeled were evaluated as feasible for injection based on-site inspection, 9-108 parcels may actually be available for injection assuming the same feasibility ratio.

As Table 2 shows, the largest sensitivity for the parcel analysis for Alternatives A-E is the assumption that parcels would require an MS4 outfall greater than 36 in at the site to receive sufficient stormwater to be feasible. The modeling results show that parcels with outfalls of that size reach the storage capacity of the infiltration basins and/or storage vaults during most storms. This indicates that the assumption is likely conservative and that the sites are storage-limited, rather than supply-limited. **Table 8** shows the number of parcels that would be available for each alternative with varying MS4 outfall assumptions.

TABLE 8
REFINED PARCEL ANALYSIS WITH VARYING MS4 OUTFALL SCREENING CRITERIA

	# of Parcels assuming MS4 >36" on parcel	# of Parcels assuming MS4 >24" on parcel	# of Parcels assuming MS4 >12" on parcel	# of Parcels assuming any size MS4 within 250 ft of parcel
A – Infiltration to Groundwater Basin	29	31	31	48
A – Injection to Groundwater Basin	9	27	32	108
B – Infiltration for Hydrology	88	189	220	617
C – Irrigation	61	89	107	255
E – Use for Treatment Wetland	100	191	221	532
Total Uses	**287**	**527**	**611**	**1,560**

Because the parcel analysis is sensitive to the MS4 assumption, results are presented in Section 3.2.3.4 for both 36 in MS4 outfalls and any outfall within 250 ft of a parcel. It is important to note that additional parcels may be available if vicinity to MS4 pipes and channels, rather than just outfalls, is considered. However, this data was not incorporated into the current analysis and should be considered as individual projects move forward.

Additionally, the parcel analysis for Alternative B, which includes green streets, does not include street right-of-ways, which could dramatically increase the number of areas available to capture stormwater. This potential will be taken into consideration in the prioritization analysis.

For Alternatives F-H, the parcel analysis was sensitive to the capacity of the nearest WWTP. If WWTPs are expanded in the future, the additional capacity at other plants could open up more opportunities. If all of the WWTP in the region had additional capacity, an additional 1,017 parcels could be included for consideration. Results based on the potential of an increased in WWTP capacity are presented as the upper range in Section 3.2.3.4.

Stormwater Use Alternative Volume Analysis

Alternatives A and B: Infiltration

For both infiltration analyses, sensitivity was evaluated for infiltration rate within each soil group. As indicated in Table 3 in Section 3.2.2.1, infiltration rates can vary significantly, even if the soil group is known. For this study, the upper limit of each range was used to determine the highest amount of stormwater reasonably infiltrated. The lower limit was used in a second analysis to investigate sensitivity, and this analysis indicated that infiltration volumes could be as much as 55% lower within the infiltration rate ranges for each soil group.

Alternative C: Irrigation

For the irrigation analysis, sensitivity was evaluated for irrigation area and for irrigation practice. An investigation of irrigation area indicated that small irrigation areas emphasize the capacity-limited response of these parcels. With small irrigation areas, stormwater captured and stored at a parcel cannot be used quickly enough to empty the storage vault before the next rainfall event, and the excess must be drained.

Irrigation use is also influenced by irrigation practice decisions. For this analysis, irrigation began after three dry days – days with less than 0.001 cfs of inflow. The number of dry days before irrigation and the threshold for defining a dry day are irrigation practice decisions made by the agency managing the project, and may vary. To test this, a case where irrigation began after seven days with zero inflow (delay of seven days, threshold of zero cfs) was performed and revealed that such a long wait and strict threshold eliminated almost all irrigation use. The other extreme – irrigation at all times – was deemed infeasible and not considered in the sensitivity analysis.

Alternative D: Rain Barrels

For the rain barrel analysis, sensitivity was evaluated for roof size, irrigation area, and regional location (or rain gage). Larger roof sizes did not result in more used volume because the rain barrels are storage-limited. Roofs 600 sf or larger resulted in the same capture and use volume. Similarly, increasing the irrigation area did not impact the results. As long as each rain barrel was used to irrigate at least 150 sf, the use volume remained the same. Lastly, the location of the rain barrel, which determines the amount of rain received, did not impact the results. The model was run for the driest rain gage, in Bonita, and was still found to be storage-limited.

The range in future rain barrel purchases in the region, as discussed in Section 3.2.3.2, shows the most sensitivity for this analysis. The range in number of rain barrels is used as the basis for the range of volumes in Section 3.2.3.4.

Alternatives E-F: Treatment Wetlands and Dry Weather Diversion to Wastewater Treatment

For analysis of dry weather flows, sensitivity was evaluated for different inflow rates and drainage areas. Inflow rates at observation stations vary by three orders of magnitude, with a median of 0.025 cfs. To capture the variation, the 25th- and 75th-percentile flows were determined (0.0124 cfs and 0.0625 cfs, respectively) and evaluated. Dry weather observation stations were also compared with the delineated parcel drainage areas in which they lie to look for correlation; however, no significant correlation was identified. This implies that using the high and low flows is appropriate for extrapolation across the San Diego region, rather than a parcel-size- or drainage area-size-based inflow.

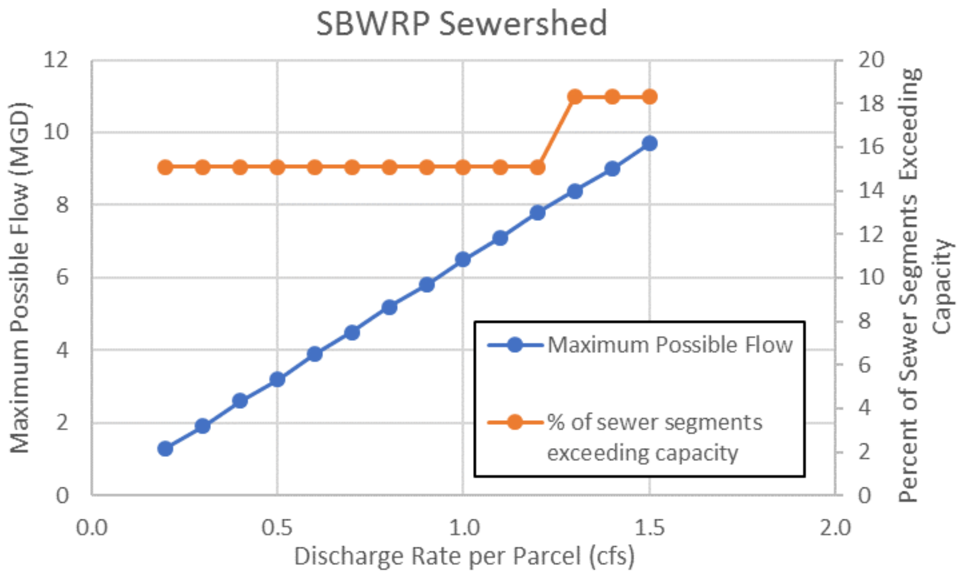
Alternatives F-H: Wastewater Treatment

In the sewer capacity analysis, sensitivity was analyzed with respect to parcel discharge rate (which is connected to parcel storage volume). A discharge rate of 0.5 cfs was assumed to provide adequate volume in both sewer systems, while not exceeding sewer capacity over the majority of each sewer system. However, parcel discharge rates ranging from 0.1 to 1.5 cfs were evaluated to determine impacts on the maximum possible stormwater flow that could be captured, and on the capacity impacts on the sewer system.

The sensitivity analysis conducted on discharge rate determined, as expected, that the maximum possible flow to the plant available from parcel discharge increases linearly with increase in parcel discharge rate. This is a direct result of the number of parcels contributing to flow with each incremental discharge rate (the number of available parcels changes with each discharge rate, as explained in the next section). On average, when the discharge flow from all parcels increases by 0.1 cfs, this results in an increase in total flow going to the downstream WWTP by about 0.6 million gallons per day in the SBWRP sewer system, (**Figure 9**) and by about 1.1 million gallons per day in the Padre Dam sewer system (**Figure 10**).

The resulting capacity of the sewer system was evaluated in terms of the percentage of the total number of sewer pipe segments in the evaluation that were deemed to exceed capacity in a given system, with an increase in parcel discharge rate. In general, the SBWRP sewer system was found to have about 15 percent of sewer segments exceeding capacity at discharge flows at or under 1.2 cfs. This value jumps to about 18 percent of all pipes when discharge rates exceed 1.2 cfs (Figure 9). The fact that even a low discharge rate results in about 15 percent of sewer segments exceeding capacity is a result of the conservative assumptions applied to the base wastewater flow. These out-of-capacity pipes at a discharge rate of 0.5 cfs or less are concentrated in regions where a major reduction in pipe size occurs, causing a bottleneck for the upstream base wastewater flow. This is explained in more detail in Appendix A.

In the Padre Dam sewer system, under 8 percent of sewer segments were found to exhibit capacity issues at parcel discharge flows 0.3 cfs or less (Figure 10). This percentage rises to about 10 percent and further at discharge flows of 0.4 cfs, to about 17 percent at 0.5 cfs, and to about a third of the system at 1.0 cfs. This is primarily due to several consecutive sewer segments upstream of the influent pump station reaching capacity with parcel flows exceeding 0.5 cfs from upstream parcels are added. In this case, additional parcel flow is likely to affect sewer capacity in the event that parcel discharges from all considered parcels reach this segment of pipe at the same time. A discharge rate of 0.5 cfs is conservatively recommended from parcels, to minimize major capacity issues in the sewer system.



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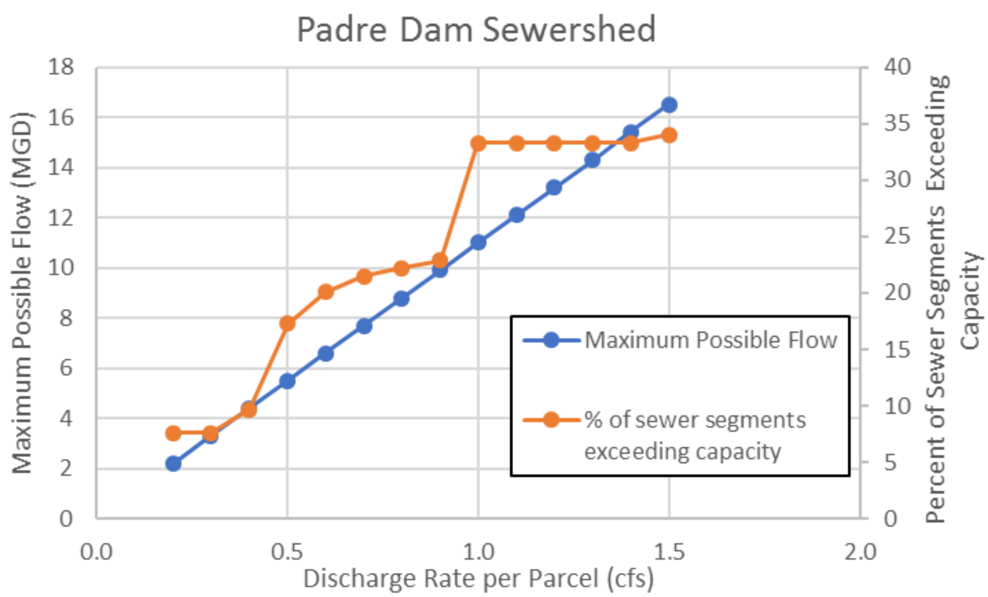
SOURCE: Brown and Caldwell 2018

Figure 9
Sensitivity of SBWRP Sewershed Model to Changes in Parcel Discharge Rate



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SOURCE: Brown and Caldwell 2018

Figure 10
Sensitivity of Padre Dam Sewershed Model to Changes in Parcel Discharge Rate

3.2.3.4 Potential Regional Stormwater Capture and Stormwater Use Alternative Estimate

Table 9 tabulates the results for each of the alternatives and presents a total regional estimate. Since many parcels could be used for multiple alternatives, the stormwater use alternative that resulted in the highest volume was chosen for the total volume calculation in the last row. The row above this shows the total if multiple uses occurred on the parcels, although the feasibility of this has not been evaluated. For example, if a parcel was identified as feasible for Alternative A and Alternative C, and the quantification resulted in 5 ac-ft/yr for Alternative A and 1.3 ac-ft/yr for Alternative C, this parcel would count toward 5 ac-ft/yr for the total (applying a single max alternative) and 6.3 ac-ft/yr for the total (applying multiples alternatives). However, the total with multiple alternatives may be overestimated since applying both alternatives to a parcel was not evaluated.

TABLE 9
TOTAL POTENTIAL REGIONAL STORMWATER CAPTURE AND USE

	# of Parcels	Total Volume (ac-ft/yr)
Alternative A – infiltration to a groundwater basin		
Infiltration basins	29 – 48	330 – 440[3]
Injection wells	9 – 108	480 – 5,700[4]
Alternative B – infiltration for hydrology	88 – 617	530 – 3,700[3]
Alternative C – irrigation	61 – 255	260 – 1,100[3]
Alternative D – irrigation for private use (rain barrels)	n/a	10 – 50
Alternative E – use for treatment wetlands	100 – 532	680 – 3,600[3]
Alternative F – dry weather diversion to wastewater treatment	123 – 1,140	420 – 3,900[5]
Alternative G-H – wastewater treatment	123 – 1,140	810 – 7,400[5]
Total (Applying multiple alternatives per parcel):	**410 – 2,700**	**3,100 – 22,000[1]**
Total (Applying single max alternative per parcel):	**211 – 977**	**2,200 – 9,400[2]**

1. Assumes basins with multiple alternatives can utilize all alternatives.
2. Assumes basins with multiple alternatives only use the highest volume alternative.
3. Assumes no MS4 requirement.
4. Assumes no MS4 requirement or soil hydrology requirement, but above a groundwater basin.
5. Assumes no capacity limit for any WWTP.

The total potential range of the stormwater volume that could be captured and used in the San Diego region varies greatly depending on the feasibility screening criteria applied that represents the constraints and opportunities for this region. The lower end of the range is based on the screening criteria applied to the public parcels as presented in Table 2. The upper end of the range represents the results of the sensitivity analysis, and modifications to these screening criteria. These results reflect the high variability associated with this feasibility-level analysis and the data set that is available for this study. Project-specific data can yield less variability.

The results of this refined parcel analysis are expectedly lower than the original estimates in the SWRP. This refined analysis applies more feasibility screening criteria to the public parcels informed by the example projects and constraints identified during the second TAC workshop, compared to the preliminary estimate presented in the SWRP. The refined screening criteria result in a much lower parcel estimate (211) compared to the SWRP (1,207), which is one reason the resulting volumes are much lower. Additionally, discussions with facility operators resulted in a lower wastewater discharge rate by an order of magnitude compared to what was used in the SWRP. This reduced the volume by over 60,000 ac-ft/yr.

Although there is high variability in the estimated regional volumes, these results provide a basis to assess each of the stormwater use alternatives for regional and jurisdictional planning as both ends of the range can inform the analysis. The results also indicate that unlike other regions, San Diego has a greater number of constraints (e.g. lower permeability soils, limited groundwater basins, and limited capacity of existing WWTP) that result in a greater sensitivity to the screening criteria applied to the parcels. These planning level estimates, along with costs to be developed in the next phase of the study, will be used as part of the prioritization process to identify the alternatives and project types that provide the best opportunities for stormwater capture and use in the San Diego Region. In addition, the prioritization of alternative uses will identify the “gates” that alternatives need to overcome and the potential “keys” that may open these gates and lead to more opportunities for stormwater capture and use in the region.

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APPENDIX A

Sewer System Evaluation for Flow Augmentation to Wastewater Treatment Plants

San Diego County Stormwater Capture and Use Feasibility Study (SWCUFS)

Sewer System Evaluation for Flow Augmentation to Wastewater Treatment Plants

1 Introduction

The SWCUFS aims to determine the potential for stormwater to be captured, stored, and discharged for beneficial use across San Diego County. The evaluation performed by Brown and Caldwell (BC) determines this potential in selected parts of the County for recycled water use via a local wastewater treatment plant. The process used here assumes the collection and storage of stormwater during rain events in parcels within the sewershed of certain local plants, followed by controlled discharge into the sanitary sewer system during periods of low sewer flow, for subsequent flow augmentation to the downstream wastewater treatment plant. The downstream plant is expected to be one that produces water for non-potable or potable recycled use, or has plans to implement or expand recycled use production in the near future.

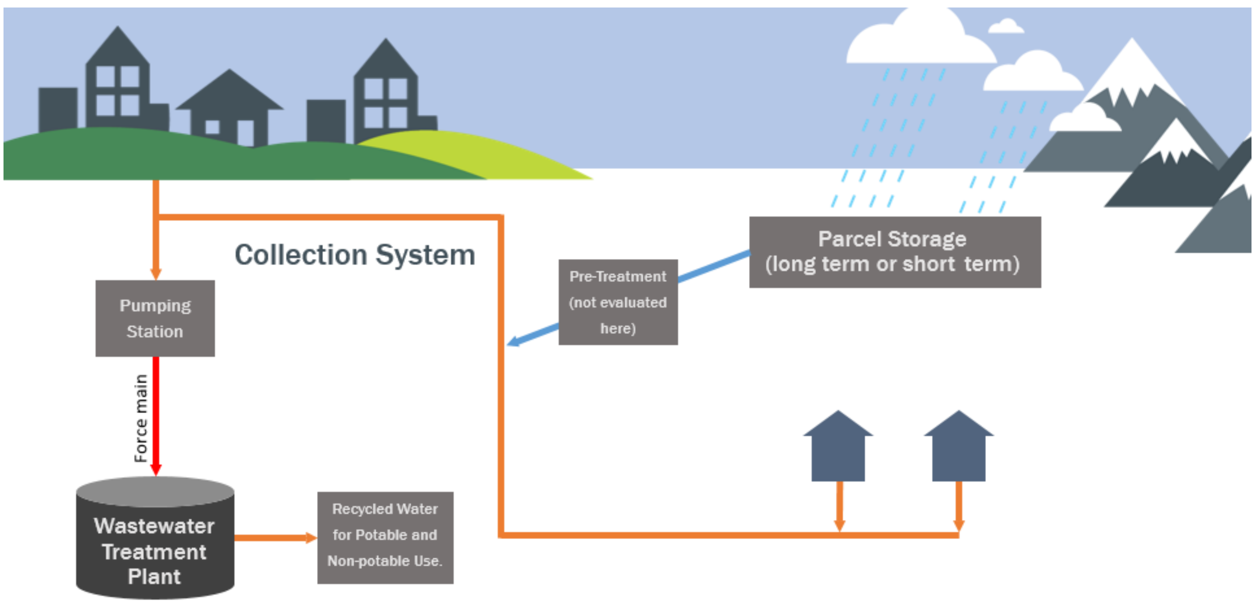

Figure 1. Stormwater capture concept for flow augmentation to sewer systems.

1.1 Selection of Sewersheds and Plants

Two major sewersheds and corresponding plants were selected for this evaluation: (1) the South Bay Water Reclamation Plant (SBWRP), operated by the City of San Diego, and a portion of its presumed sewershed, and (2) the Ray Stoyer Water Reclamation Facility (RSWRF, or referred to here as Padre Dam), operated by the Padre Dam Municipal Water District (PDMWD, or Padre Dam), and a portion of its presumed sewershed. The former sewershed is referred to in the text of this evaluation as SBWRP, and the latter as Padre Dam. Of all the sewersheds, sewer systems and wastewater treatment systems in the County, these two were chosen for a sewer system evaluation owing to major recycled water production plans in the near future at both plants, and the fact that several parcels exist in the sewersheds of both these plants. Stormwater may therefore serve as a water source to augment flow to both these plants. While these two plants/sewersheds are not the only candidates for this evaluation within the County, the intention is for this high-level evaluation of these two systems to serve as a template for subsequent evaluations at other locations.

1.2 Objectives of Analysis

The objectives of the analysis of the two sewer systems described above include:

1. Determine the total quantity of stormwater available via capture and controlled discharge, to augment influent flow into the downstream wastewater treatment plant.

2. Determine any capacity limitations on sanitary sewers if a controlled discharge is augmented to the base wastewater flow.

2 Evaluation Method

2.1 Assumptions:

1. Several stormwater capture parcels were identified in the vicinity of major sewers in both sewersheds. These parcels were screened subjectively, and it was assumed that certain characteristics, like a steep slope, the presence of several buildings, and location within a potentially ecologically sensitive area, would either cause a parcel to be completely eliminated, or have a part of its area eliminated from being useable for storage prior to discharge to a sewer system.
2. A constant discharge flow of captured stormwater into the sewer system was assumed from all useable parcels. In this evaluation, this flow was 0.5 cfs.
3. Since both the wastewater treatment plants considered in this evaluation are geared toward recycled water production, and take influent flows as needed to meet these targets, their sewersheds are more variable than represented in these calculations, and are linked to neighboring sewersheds within the County. This evaluation assumes the major (24" diameter and greater for SBWRP, and 21" diameter and greater for Padre Dam) sewers in the vicinity of each plant contribute wastewater to the plant.
4. These major sewers (and no smaller diameter sewers) were used for augmentation with parcel flow. A buffer zone of 200 feet on either side of each major sewer was assumed to be the maximum distance to convey or pump discharge flows from parcels to the sewers. Only parcels that intersect this 200-foot buffer were considered for this analysis.
5. The major assumption in sewers was that a base wastewater flow exists, and is augmented by parcel flow, if there is an adjacent parcel, or parcels upstream. For each sewer segment in the descriptions shown below, the base wastewater flow was calculated assuming the sewer flows 50% full on average and at a velocity of 8 ft/s during low flow conditions. Base wastewater flows were generally calculated for each segment separately and were not added cumulatively to downstream lines, except under certain circumstances, as described below.
6. The base wastewater flow used in these calculations is not meant to be representative of actual average flow in the sewer lines during low flow conditions. It is meant to be a conservative estimate of the wastewater flow likely experienced by each sewer segment, to which parcel flow may be added, so that available capacity to take in additional flows from

parcels can be determined. The fact that the base wastewater assumptions are not representative of actual wastewater flows is evident from the fact that the base wastewater flows used in these calculations were found to add up to yield a much higher flow to each plant than the plants actually receive.

7. Future sewer system connections or plans to replace/relocated sewers were not accounted for in these calculations.
8. Additionally, sewer capacity was deemed to have been reached in gravity sewers when the sewer flows at 75% full as a result of additional discharge from parcels. In force mains, capacity is assumed to have been reached when the flow velocity exceeds 8 ft/s.
9. The sewer system calculations were run assuming that all parcels are discharging to a sewer system such that a given segment sees all upstream parcel flows flowing through it at the same time. This is a very conservative assumption, and is unlikely to hold true in practice. It should be possible to control discharge from a given parcel based on downstream sewer capacity at a given time.
10. The conveyance and/or pumping needs to transfer stored stormwater to the sanitary sewer are not accounted for in this evaluation. It is assumed that a flow of 0.5 cfs can be delivered from a useable parcel to an adjacent sewer during periods of low flow.

2.2 Parcel Volume Calculations

City Sewer GIS Layers were acquired from SANGIS for the SBWRP sewer system, and Padre Dam Sewer GIS Layers were acquired from Padre Dam. The GIS layers were then filtered to sewers of diameter 24" or greater in the SBWRP sewer system, and 21" or greater in the Padre Dam sewer system. Parcel information was acquired for parcels within 200 feet of the existing sewer lines for both sewer systems from ESA. Using larger sewers helps ensure adequate capacity for stormwater input, and the use of a 200-foot buffer ensures an upper limit on infrastructure needed to convey or pump stored stormwater to the sanitary sewer. All parcels that met these criteria were identified.

These parcels were evaluated, and subjective determinations were made of the useable area from each parcel for capture. Some general rules that were used include:

1. That parcels located on high-slope land, of roughly more than 2%, would not be useable. This slope cutoff was implemented because of the potential logistical complications involved in planning storage and subsequent controlled discharge on a parcel at steep grade. 2 percent was determined to be a reasonable rough upper limit on grade for parcels. This was implemented by visually scanning several locations on each parcel for elevation and distance, and estimating slopes. Whole parcels, or portions thereof that were estimated to be at about 2 percent slope or greater were considered not useable.
2. That sections of parcels with buildings would not be useable.
3. That parking lots and undeveloped plots of land are generally useable.
4. That potentially ecologically sensitive land, like state parks, wetland reserves, or riparian land, would not be useable.

A value for minimum and maximum percent useable area was thus assigned to each parcel, and the value for maximum useable area was applied to all subsequent calculations, to help generate the maximum possible storage volume from a given parcel. These values were combined with the total acreage for the land provided in the parcel data, as well as a storage "vault" depth assumption of 6 feet, as recommended by ESA, to determine a minimum and maximum useable volume of stormwater.

To simplify assumptions across all parcels and both sewer systems, and after a sensitivity analysis (documented in a later section) it was decided that a constant discharge flow of 0.5 cubic feet per second (cfs) would be assumed for all parcels. In other words, this is the flow at which any given parcel would discharge into a sanitary sewer when there is stored volume from the parcel, and when low flow conditions exist in the sewer system. This flow value was the result of several iterations of sewer system calculations, as described in Section 2.3, and the subsequent determination that a discharge rate of 0.5 cfs applied to all parcels would ensure that the majority of sewer lines would have capacity with parcel flows added in.

2.3 Sewer Capacity Calculations

Each sewer system was divided into "branches", each of which was evaluated individually in terms of capacity of each constituent segment, and the resulting flows were then brought together based on the branching pattern. The sewer segments (sewer pipes, identified in the GIS data by "Facility Sequence ID") in each of these branches were sequentially ordered along the presumed direction of flow, and adjacent parcels were identified along each sewer segment. The previously calculated flows from each parcel (0.5 cfs per parcel, as described in the previous section) were made cumulative, moving downstream. In addition, the base wastewater flow was determined based on the assumptions made above.

For each pipe segment within each branch, a base wastewater flow was assumed within the pipe. This base wastewater flow was usually calculated assuming it accounts for the pipe flowing 50% full (Figure 2). In cases where a pipe diameter was smaller than upstream pipe diameters, the base wastewater flow calculated for the larger upstream pipe was used for the smaller downstream pipe (Figure 3). For force mains, the base wastewater flow directly upstream of the pump station that the force main emerges from was carried into the force main. In addition to base wastewater flow, parcel flows were also calculated for each pipe segment. Parcel flows were made cumulative, moving upstream to downstream along a branch, and cumulative parcel flow from parcels adjacent to a given segment and all parcels upstream of it, was added to the base wastewater flow.

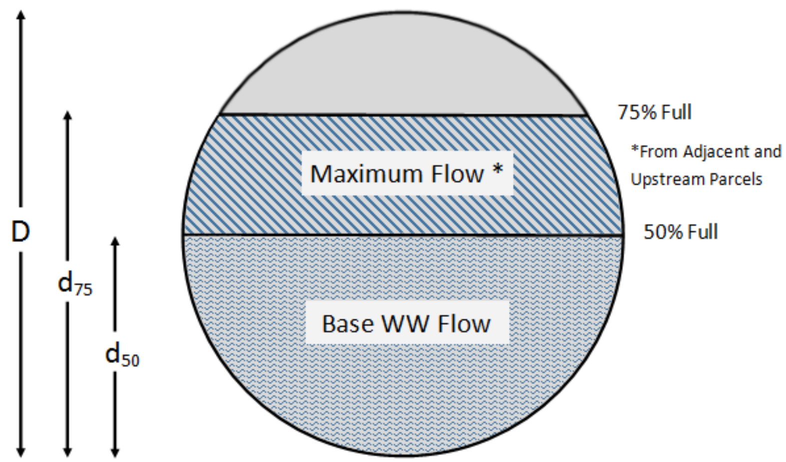

Figure 2. Gravity sewer assumptions for base wastewater flow (50% full) and capacity (75% full).

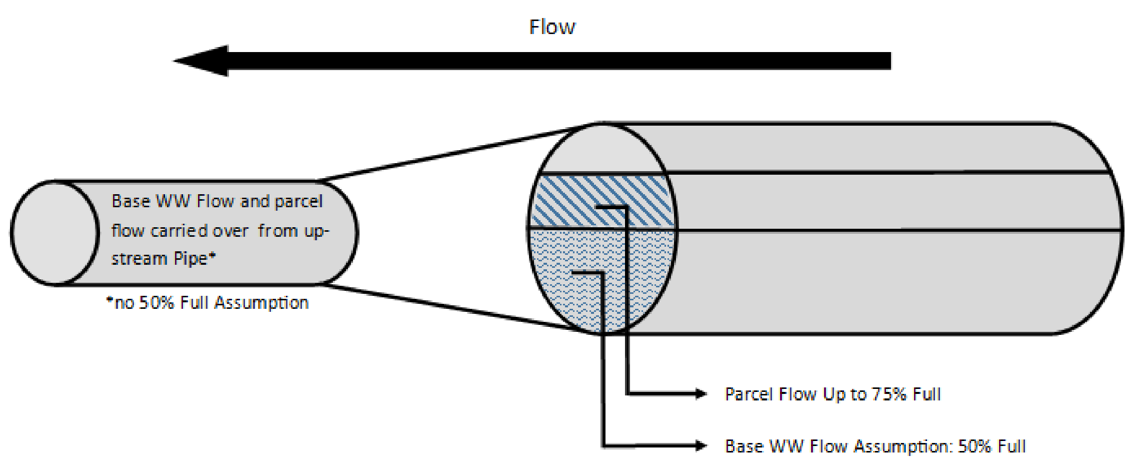

Figure 3. Assumptions for flow in gravity sewers when pipe diameter decreases going downstream.

For gravity sewers, the above analysis would yield a base wastewater flow, plus a cumulative parcel flow for each segment. This total flow was used to recalculate d/D (percent full), which would be greater than 50%, given the additional parcel flow. If the recalculated d/D value was at 75% or less, a given segment was assumed to have capacity for parcel discharge. If the recalculated d/D value was found to be greater than 75%, the segment was determined to potentially have capacity issues in terms of accepting parcel flows in addition to its base wastewater flow.

For force mains, the base wastewater flow, which represents the total flow entering the pump station upstream of the force main, as well as total parcel flows upstream of the force main segment were added up to yield a total flow (Figure 4). This total flow was used to calculate velocity in the main, assuming force mains customarily run at 100% full. If the calculated velocity was between 4 and 8 ft/s, the force main segment was assumed to have the necessary capacity. If the calculation for a force main segment yielded a velocity greater than 8 ft/s, capacity issues were assumed to exist. Generally, when force main velocities were lower than 4 ft/s, this was not considered a major issue, as the base wastewater flow by itself would also theoretically yield a lower velocity, and it was assumed that adding parcel flow to such segments would not result in a final velocity greater than 8 ft/s.

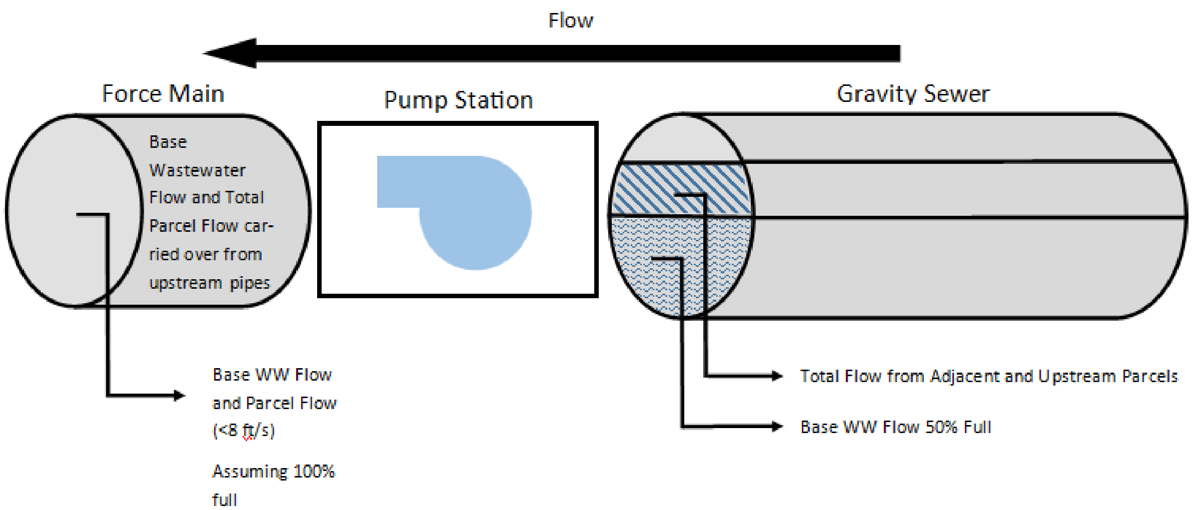

Figure 4. Assumptions for force mains.

The analysis described above yielded information on the potential capacity of each sewer segment in the system, identifying where in the sewer system any capacity issues may exist if parcel flows are added to the system. The total flow from parcels available to the downstream plant was also calculated in this analysis. As parcel flows accumulated going downstream in the sewer system, the total parcel flow from each branch was calculated (this was more easily calculated based on the number of useable parcels within each branch and the assumption of 0.5 cfs discharge flow per parcel), and added to the parcel flow to downstream branches. The results of this sewer capacity analysis are summarized in sections 3.2 (SBWRP) and 3.3 (Padre Dam).

3 Results

3.1 Parcel Selection

In total, 122 parcels (35 in the Padre Dam sewershed and 87 in the SBWRP sewershed) were identified across both sewersheds that were within 200 feet of major sewer lines (24” or greater for SBWRP sewershed and 21” or greater for Padre Dam sewershed). Of these, 82 were determined to have a nonzero useable volume (at least some portion of the parcel was deemed useable to collect and store drainage from a storm). 61 of these were in the SBWRP sewershed, while 21 of these were in the Padre dam sewershed. Finally, two major branches were eliminated in the SBWRP sewershed (Branches H and I; branches described in detail in Section 3.2) because the wastewater from these branches were found to not normally flow toward SBWRP. Additionally, several parcels were eliminated from both sewersheds due to vicinity to a force main as opposed to a gravity sewer. The infrastructure requirements to discharge from a parcel to a force main directly would make capture infeasible for such parcels. These two additional constraints resulted in the elimination of 51 parcels from the SBWRP sewershed and 3 parcels from the Padre Dam sewershed, resulting in 10 useable parcels in the former, and 17 useable parcels in the latter.

Table 1. Summary of Parcels Used in Evaluation			
Sewershed	Total No. of Parcels[1]	No. of Parcels with Useable Area[2]	No. of Parcels After Other Constraints Applied[3]
SBWRP	87	61	10
Padre Dam	35	21	17

1. Total number of parcels identified within 200 feet of a major sewer line.
2. Number of parcels of those identified that were deemed to have a useable area, from subjective evaluation of the land on each parcel.
3. Other constraints include (1) the fact that some parcels lay along force mains, the infrastructure required to connect to a force main was assumed to make capture infeasible from such parcels, (2) The removal of two major branches along the SBWRP sewershed because they were found to not normally flow to SBWRP.

3.2 Sewer Capacity Analysis (SBWRP Sewer System)

The SBWRP sewer system was split into branches of the major sewers for easier evaluation. The SBWRP map (Figure 5) shows the layout and general assumptions. The major flows used are from branches A thru E. To summarize:

1. Branch A: A southeastern section that feeds into the main sewer system through smaller pipes.
2. Branch B: A major trunk sewer with flows from the southern part of the sewer system, leading north to the Grove Ave Pump Station.
3. Branch C: A trunk sewer/collector from the western reaches of the sewer system, flowing east to the Otay River Pump Station.
4. Branch D: A force main line from the Otay River Pump Station, leading to the Grove Ave Pump Station.
5. Branch E: A force main line conveying wastewater from the Grove Ave Pump Station to SBWRP.
6. Branch F: A force main line conveying some flows from Mexico (likely storm flows also) through the Tijuana River National Estuarine Reserve to the South Bay International Plant. We assume that the flow from Branch F does not go to SBWRP.
7. Branch G: A collector in the central part of the sewer system that appears to flow north past the Otay River Pump Station, that does not appear to send flows to SBWRP.
8. Branch H: A collector bringing flows west along the Otay River, which appears to join the main metro interceptor, along with Branch G, heading north towards the Point Loma Wastewater Treatment Plant. These flows are assumed to not normally flow to SBWRP.
9. Branch I: portion of the south metro interceptor, flowing north toward the Point Loma WWTP. These flows were also assumed to not normally flow to SBWRP.

The major flows contributing to the project and evaluated herein are from Branches A thru E.

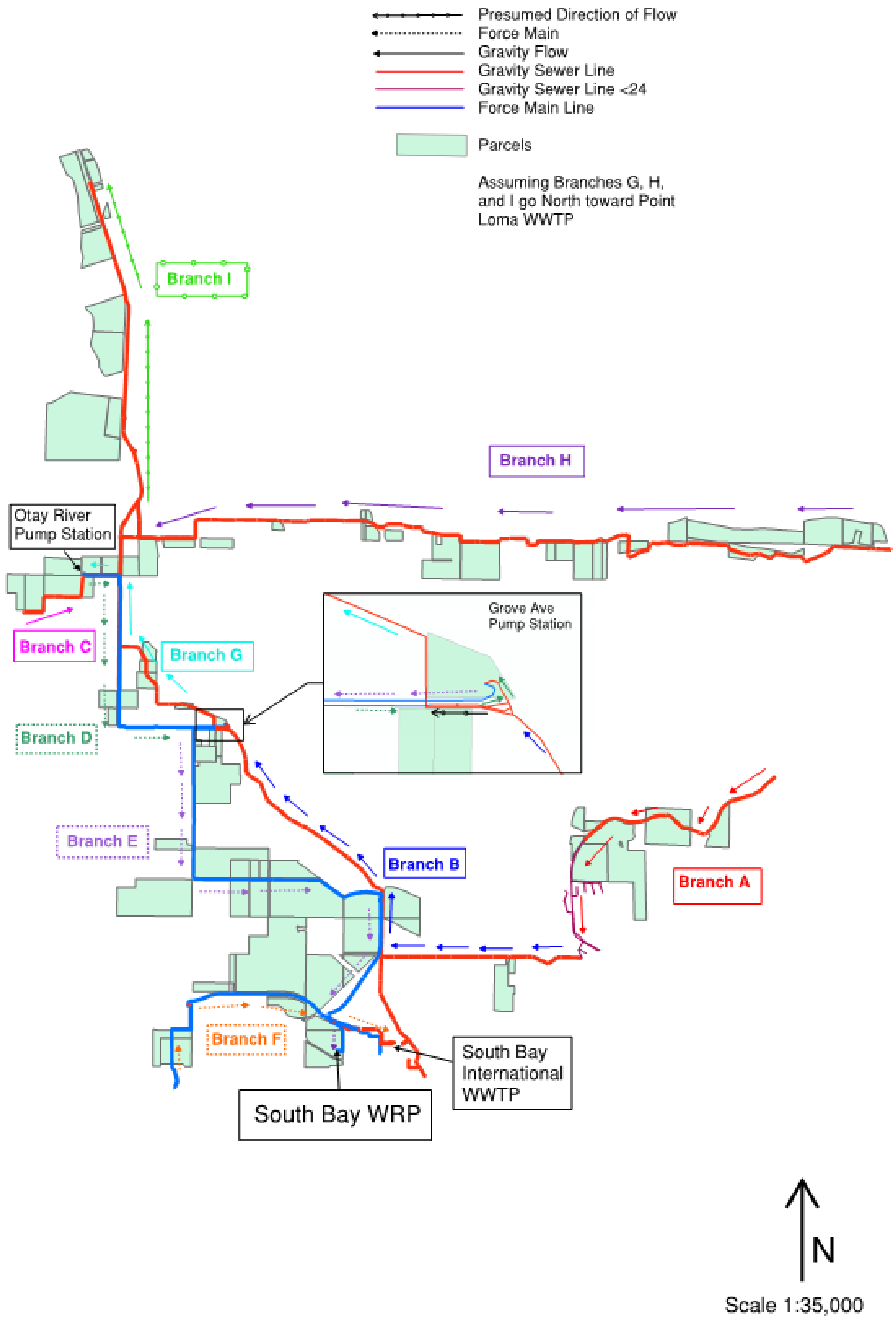

Figure 5. Layout of major sewer branches and parcels evaluated for stormwater capture in the SBWRP sewershed.

In terms of sewer system capacity to handle parcel flows, the analysis showed that the majority of the evaluated sewer system did not exhibit capacity issues as a result of parcel inflow. The only capacity issues that were encountered were as a result of a major reduction in sewer size in Branch A, from 42 inches to 10 inches. A close review of the available GIS sewer data indicated that sewer flow was in the presumed direction, with a sharp size reduction. It must be noted that the capacity issues encountered here were the result of the base wastewater flow, and not the additional parcel flow. In total, about 15 percent of the total number of sewer segments evaluated exhibited capacity issues as described above, not as a consequence of added parcel flows.

In terms of total possible additional flow available to SBWRP, as shown in the attached sewer system map, branches were added as follows: Branch B received total parcel flow from Branch A; Branch D received total parcel flow from Branch C; Branch E received total parcel flow from Branches B (including Branch A) and D (including Branch C). The total parcel flow at the end of Branch E was determined to flow into SBWRP. This total (maximum) flow was determined to be about 5.0 cfs, or 3.2 mgd. Note that this represents the maximum possible flow to the plant, and actual flows from parcels are likely to be lower. These flows are summarized in Table 2.

Table 2. Summary of Total Parcel Flow by Branch in the SBWRP Sewer System

Branch	Upstream Branch(es)	Upstream Parcel Flow (cfs)	Branch Parcel Flow (cfs)	Total Parcel Flow (cfs)
A	None	0.0	2.5	2.5
B	A	2.5	0.5	3.0
C	None	0.0	2.0	2.0
D	C	2.0	0.0	2.0
E	B, D	5.0	0.0	5.0
Total to SBWRP[1]				5.0

1. The total flow shown to SBWRP determined as a result of parcels in branches A thru E represents the maximum possible flow, assuming all parcels are discharging at the same time, and not accounting for transit time in the sewer system. Actual flow seen at the plant would be lower.

3.3 Sewer Capacity Analysis (Padre Dam Sewer System)

The calculation procedures for the Padre Dam sewer system were the same as those described for the SBWRP sewer system. The branches used to split up this system are as described below, and a layout is shown in Figure 6:

1. Branch A: A line coming in from the west, from Mission Trails Regional Park, feeding into Branch B.
2. Branch B: A southeast section in the vicinity of Gillespie air field, feeding into a main southern section via smaller pipes. Branch B was also assumed to take in flows from Branches A, C and D, before entering the RSWRF Influent Pump Station.
3. Branch C: A major line coming in from the eastern section of the sewer system, feeding into Branch B.
4. Branch D: A small section containing one major parcel, feeding into Branch B.
5. Branch E: A small section containing two major parcels, feeding into Branch B.

6. RSWRF Influent Pump Station: Receives all flow from Branch B, which, at several points in its flow, receives flows from Branches A, C, D and E.
7. Branch F: Assumed to be a force main line, sending flow from the influent pump station to RSWRF.

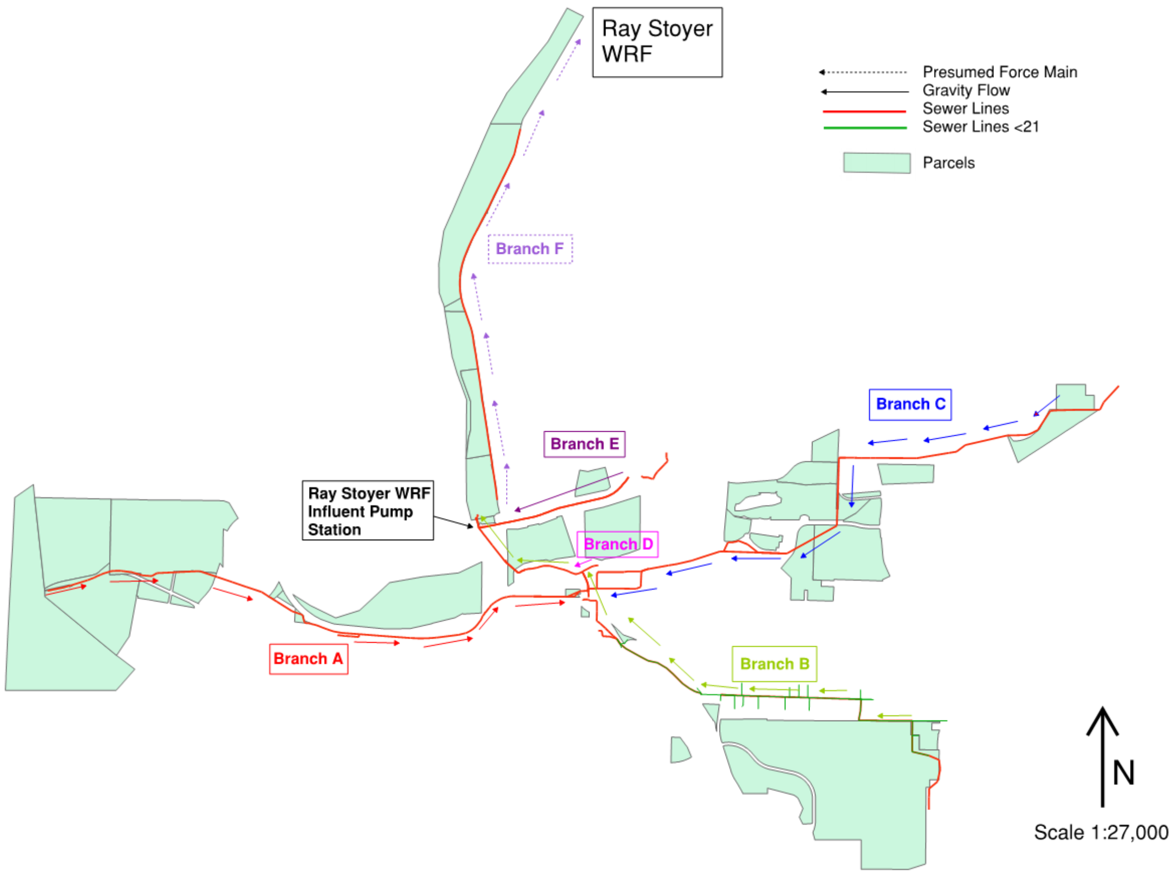

Figure 6. Layout of major sewer branches and parcels evaluated for stormwater capture in the Padre Dam sewershed.

Effectively, Branches A, C, D and E were assumed to flow into Branch B at varying locations. Branch B flows to the influent pump station, from where Branch F arises as a force main, and flows to RSWRF. All calculations were performed as described above; capacity was determined individually for each sewer segment as described above, and the total parcel flow from each branch, and going into RSWRF was determined, summarized in Table 3.

In terms of sewer capacity, the majority of the system was found to experience no capacity issues as a result of parcel flow input. Notably, the first 15-inch presumed force main emerging from the influent pump station was found to have potential capacity issues with added parcel flows. Other sewer segments that showed potential capacity issues were primarily gravity sewers where a reduction in size resulted in a larger base wastewater flow from a larger upstream pipe entering a smaller downstream pipe. This was found to occur in parts of branches A, B and C. The gravity sewer capacity issues were found to be unrelated to parcel flow input. In total, about 17 percent of the total number of sewer segments evaluated exhibited capacity issues at the 0.5 cfs parcel discharge rate.

The evaluation also yielded the total (maximum) flow potentially available to RSWRF from parcels. This was determined to be about 8.5 cfs, or 5.5 mgd. Note that this represents the maximum possible flow to the plant, and actual flows from parcels are likely to be lower. The flows from each branch in the sewer system are summarized in Table 2.

Table 3. Summary of Total Parcel Flow by Branch in the Padre Dam Sewer System

Branch	Connecting/ Upstream Branch(es)	Connecting Branch Parcel Flow (cfs)	Branch Parcel Flow (cfs)	Total Parcel Flow (cfs)
A	None	0.0	1.0	1.0
B	A, C, D, E	6.5	2.0	8.5
C	None	2.0	4.5	4.5
D	None	0.0	0.5	0.5
E	None	0.0	0.5	0.5
F	B	8.5	0.0	8.5
Total to RSWRF[1]				8.5

1. The total flow shown to RSWRF determined as a result of parcels in branches A thru E represents the maximum possible flow, assuming all parcels are discharging at the same time, and not accounting for transit time in the sewer system. Actual flow seen at the plant would be lower.

4 Sensitivity Analysis on Parcel Discharge Rate

In the sewer capacity analysis, sensitivity was analyzed with respect to parcel discharge rate (which is connected to parcel storage volume). A discharge rate of 0.5 cfs was assumed to provide adequate stormwater volume in both sewer systems while not exceeding sewer capacity over the majority of each sewer system. However, parcel discharge rates ranging from 0.1 to 1.5 cfs were evaluated, to determine impacts on the maximum possible stormwater flow that could be captured, and on the capacity impacts on the sewer system.

The sensitivity analysis conducted on discharge rate determined, as expected, that the maximum possible flow to the plant available from parcel discharge increases linearly with increase in parcel discharge rate. This is a direct result of the number of parcels contributing to flow with each incremental discharge rate (the number of available parcels changes with each discharge rate, as explained in the next section). On average, when the discharge flow from all parcels increases by 0.1 cfs, this results in an increase in total flow going to the downstream wastewater treatment plant by about 0.6 MGD in the SBWRP sewer system, (Figure 7) and by about 1.1 MGD in the Padre Dam sewer system (Figure 8).

The resulting capacity of the sewer system was evaluated in terms of the percentage of the total number of sewer pipe segments in the evaluation that were deemed to exceed capacity in a given system, with an increase in parcel discharge rate. In general, the SBWRP sewer system was found to have about 15 percent of sewer segments exceeding capacity at discharge flows at or under 1.2 cfs. This value jumps to about 18 percent of all pipes when discharge rates exceed 1.2 cfs (Figure 7). The fact that even a low discharge rate results in about 15 percent of sewer segments exceeding capacity is a result of the conservative assumptions applied to the base wastewater flow. These out-of-capacity pipes at a discharge rate of 0.5 cfs or less are concentrated in regions where a major reduction in pipe size occurs, causing a bottleneck for the upstream base wastewater flow. This is explained in the previous section.

In the Padre Dam sewer system, under 8 percent of sewer segments were found to exhibit capacity issues at parcel discharge flows 0.3 cfs or less (Figure 8). This percentage rises to about 10 percent and further at discharge flows of 0.4 cfs, to about 17 percent at 0.5 cfs, and to about a third of the system at 1.0 cfs. This is primarily due to several consecutive sewer segments upstream of the influent pump station reaching capacity when parcel flows exceeding 0.5 cfs from upstream parcels are added. In this case, additional parcel flow is likely to affect sewer capacity in the event that parcel discharges from all considered parcels reach this segment of pipe at the same time. A discharge rate of 0.5 cfs is conservatively recommended from parcels, to minimize major capacity issues in the sewer system.

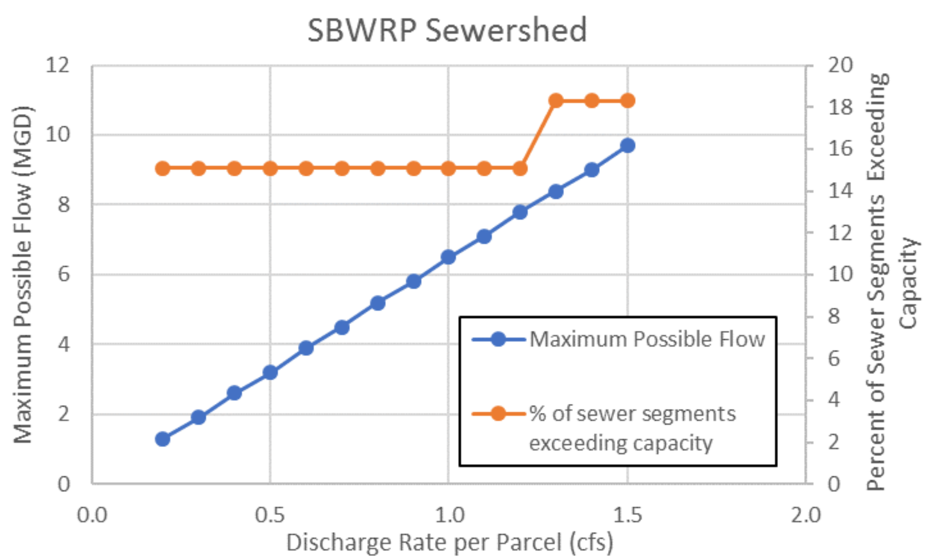

Figure 7. Sensitivity of SBWRP sewer system model to changes in parcel discharge rate.

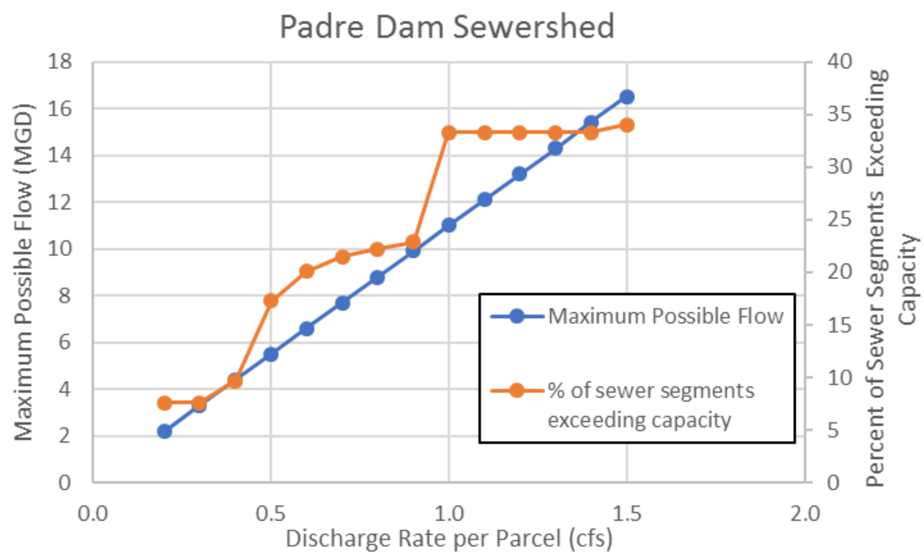

Figure 8. Sensitivity of Padre Dam sewer system model to changes in parcel discharge rate.

5 Conclusions

This evaluation was performed with two major objectives:

1. Determine the total quantity of stormwater available to augment influent flow into the downstream wastewater treatment plant.

2. Determine any capacity limitations on sanitary sewers if controlled discharges of stormwater are augmented to the base wastewater flow.

Tables 2 and 3 summarize the maximum potential flows estimated to be available to SBWRP and RSWRF respectively. Up to 3.2 mgd is available in the SBWRP sewershed, and up to 5.5 mgd is available in the Padre Dam sewershed. Note that these estimates are higher than actual flows that the plants would see due to captured stormwater, because they are based on the assumption that all parcels are draining at the same time and do not account for transit time within the sewer system. However, they can be used for high-level planning, and for a subsequent WWTP treatment feasibility evaluation.

While the majority of both sewer systems were found to have capacity to handle additional parcel flows, some capacity limitations were identified in the sewer systems. The major issues arose from reductions in pipe size along a given branch for gravity sewers, and from added flow to a single force main segment in the Padre Dam sewer system. This was evident in Branches B and C, due primarily to added flows from upstream branches and subsequent reductions in pipe size. If projects involving either of these two sewersheds are implemented, more detailed sewer system modeling is recommended, using the most recent sewer data, to ensure that actual capacity for parcel flow exists.