APPENDIX C

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.

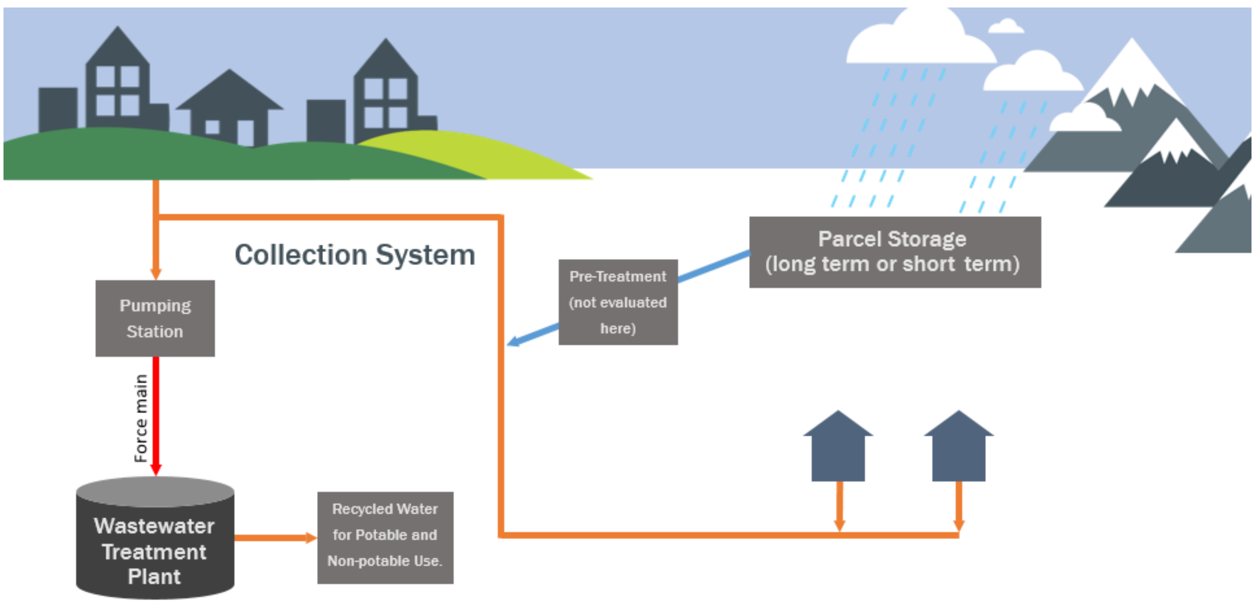

Figure 1. Stormwater capture concept for flow augmentation to sewer systems.

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.

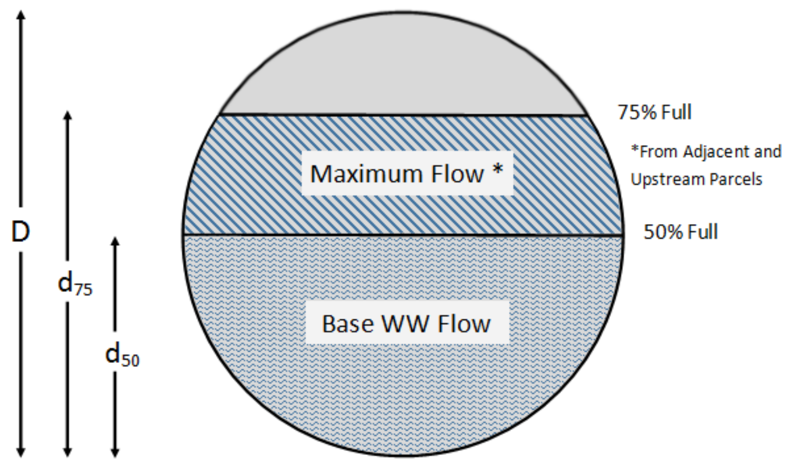

Figure 2. Gravity sewer assumptions for base wastewater flow (50% full) and capacity (75% full).

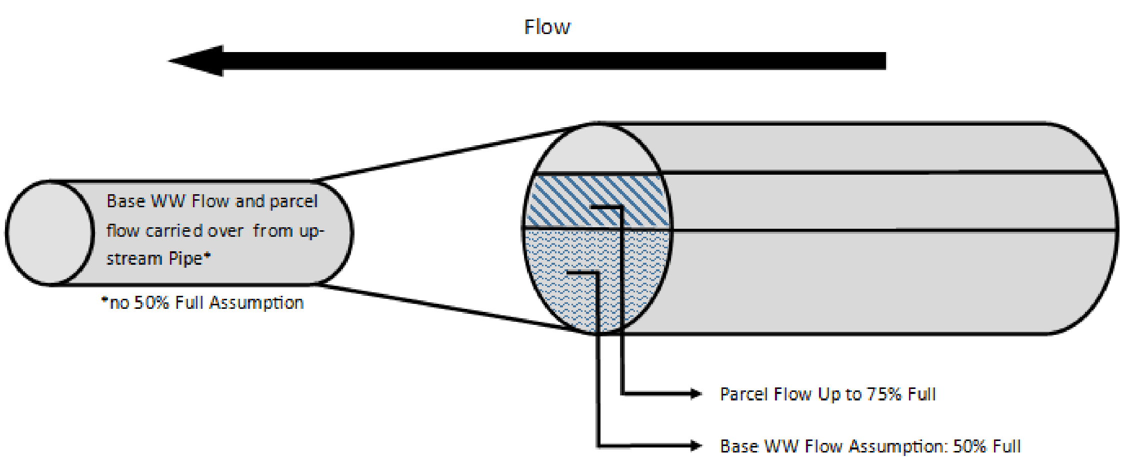

Figure 3. Assumptions for flow in gravity sewers when pipe diameter decreases going downstream.

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.

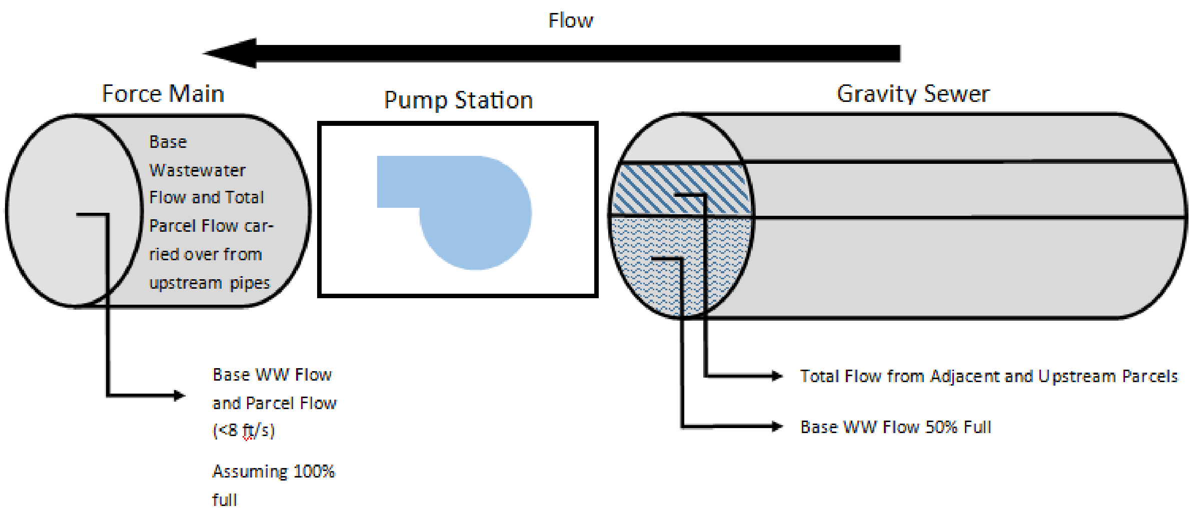

Figure 4. Assumptions for force mains.

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.

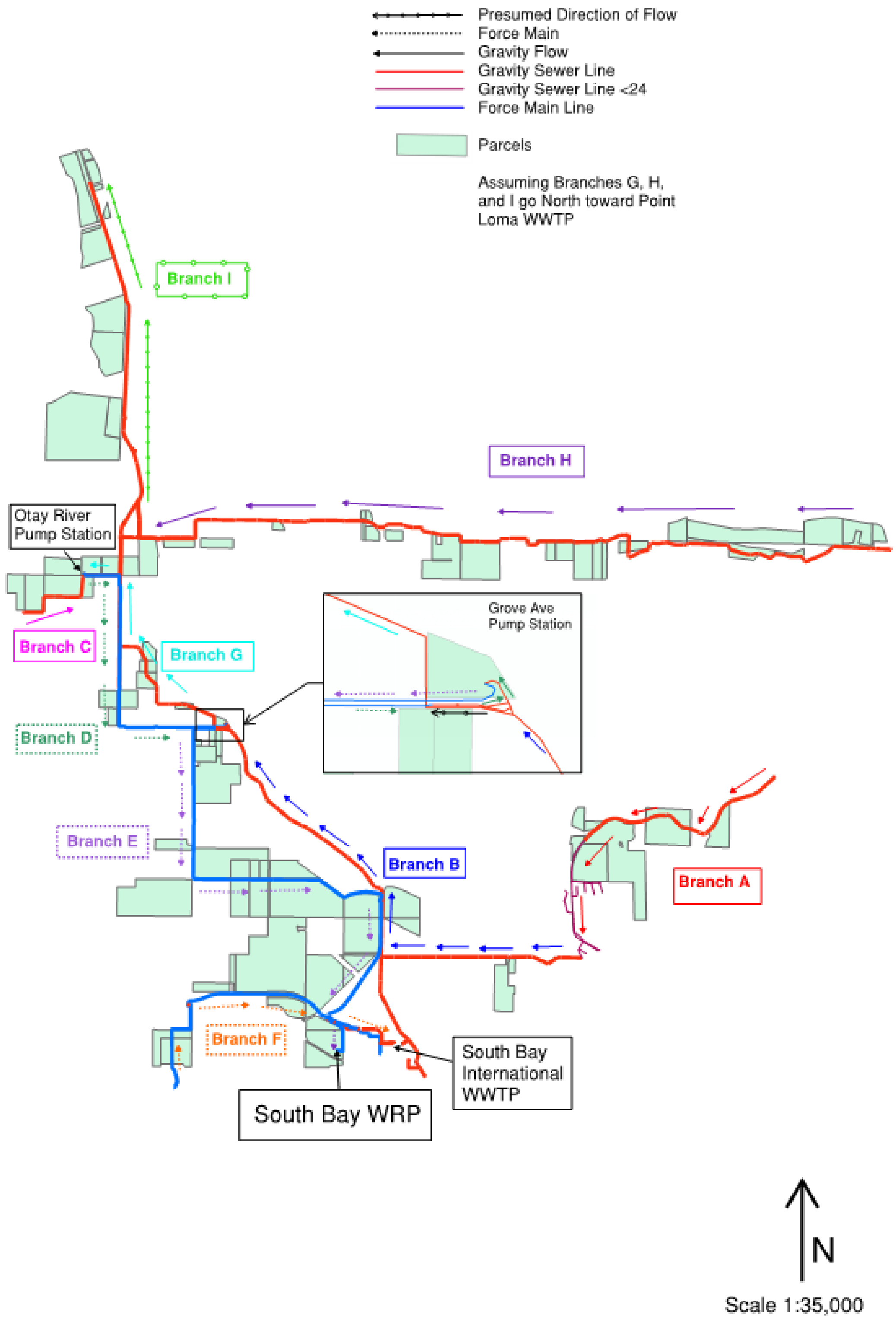

Figure 5. Layout of major sewer branches and parcels evaluated for stormwater capture in the SBWRP sewershed.

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.

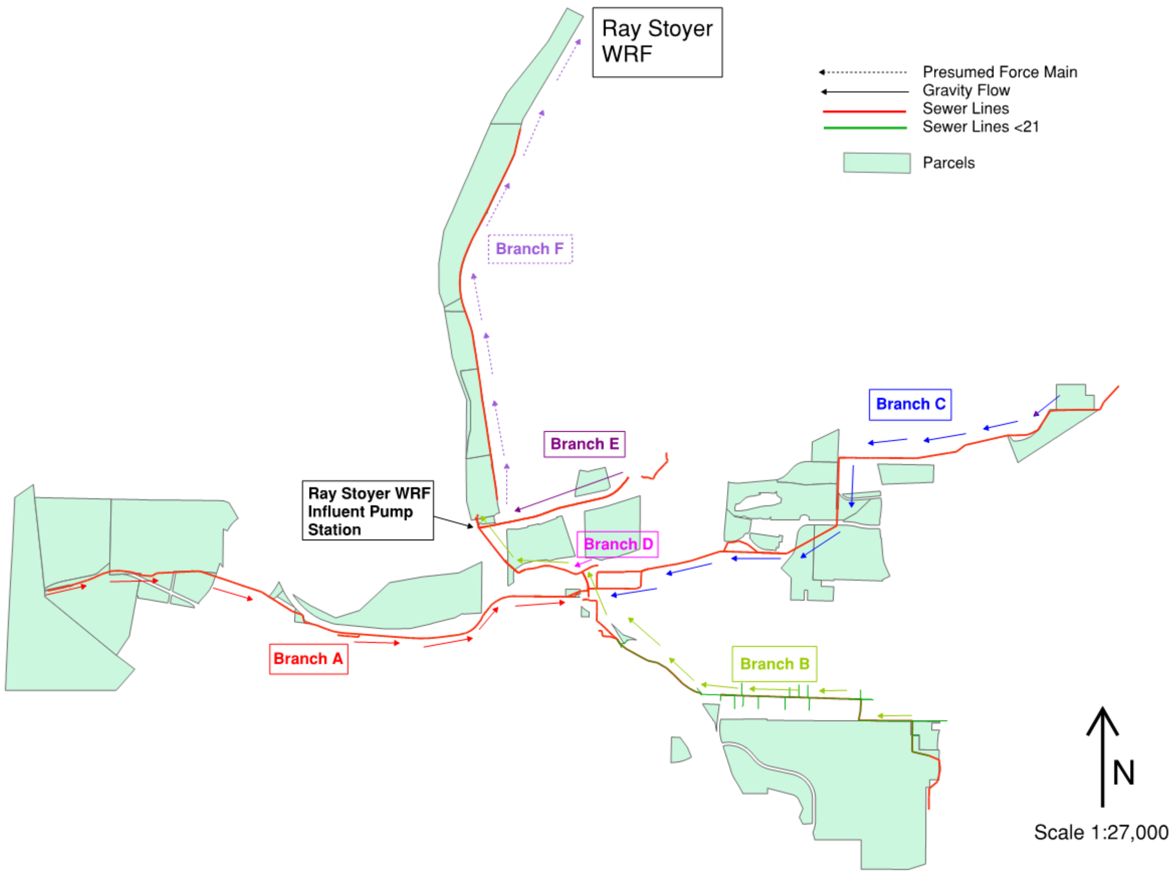

Figure 6. Layout of major sewer branches and parcels evaluated for stormwater capture in the Padre Dam sewershed.

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 outof-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.

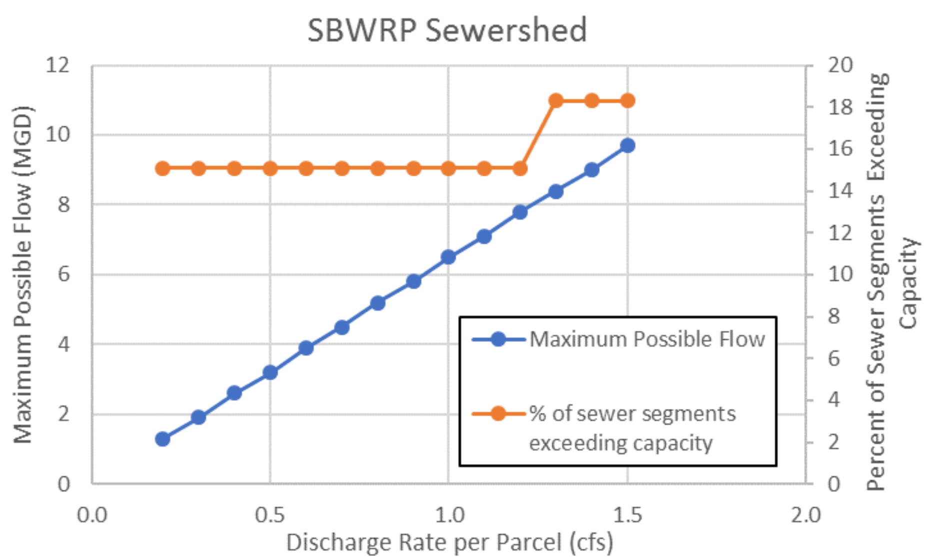

Figure 7. Sensitivity of SBWRP sewer system model to changes in parcel discharge rate.

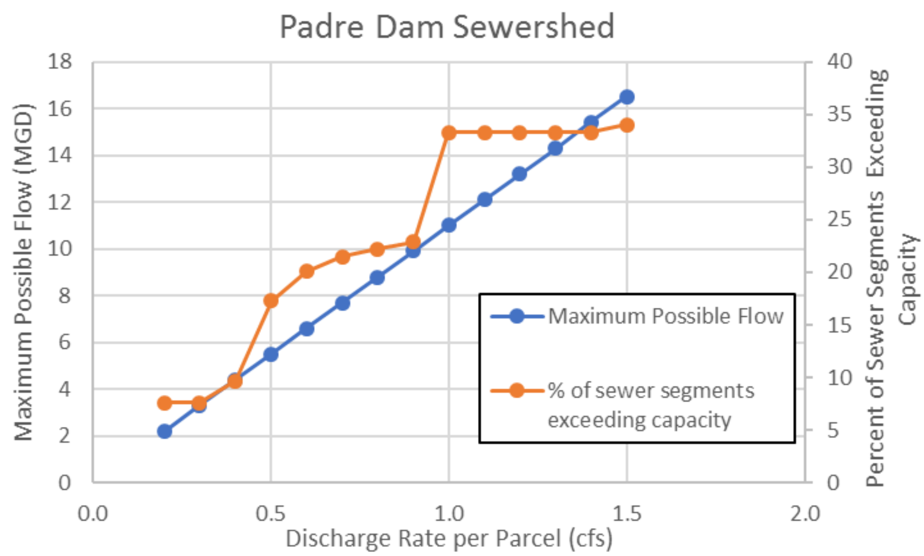

Figure 8. Sensitivity of Padre Dam sewer system model to changes in parcel discharge rate.

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.