City of Redding

WASTEWATER UTILITY MASTER PLAN 2016 ADDENDUM

Draft

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Prepared by

City of Redding Public Works Department

Field Operations Division

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Chapter 1. Introduction

1.1 Purpose

The purpose for this update is to provide an adjustment to the Capital Improvement Plan for the Wastewater Utility that takes into account the current population projections, projects that have already been completed, revises the forecast project needs, and revisits the financial needs. The update addresses the wastewater collection system needs through a revised evaluation of the collection system, operations and maintenance, and capital replacement of aging components of the system. It is not the intent of this document to replace the Wastewater Utility Master Plan 2012 but to provide additional information and analysis revising and updating critical elements of the plan.

1.2 Objective

The primary goals of the WWMP Update 2016 are to identify the remaining projects within the collection and treatment systems and develop a prioritized list of recommended capital projects. The effort met these goals by:

- Development of new sewer demand projections within the Wastewater Utility Service Area
- Performing a cursory review of the collection system computer model to verify completeness. Revising the collection system computer model to include additional major projects constructed within the last four years.
- Analyzing the existing collection system under current population levels to determine locations where improvements are necessary.
- Analyzing the collection system again and make improvement recommendations for each sequential planning horizon adding the prior recommended projects and increasing demand to account for population growth.
- Prioritizing the recommended improvements and update planning level estimates of construction cost.
- Integrating the remaining project recommendations and cost projections from both WWTP facility plans.
- Developing a revised Capital Improvement Plan
- Prepareing a financial comparison between existing revenue streams and utility budget needs.

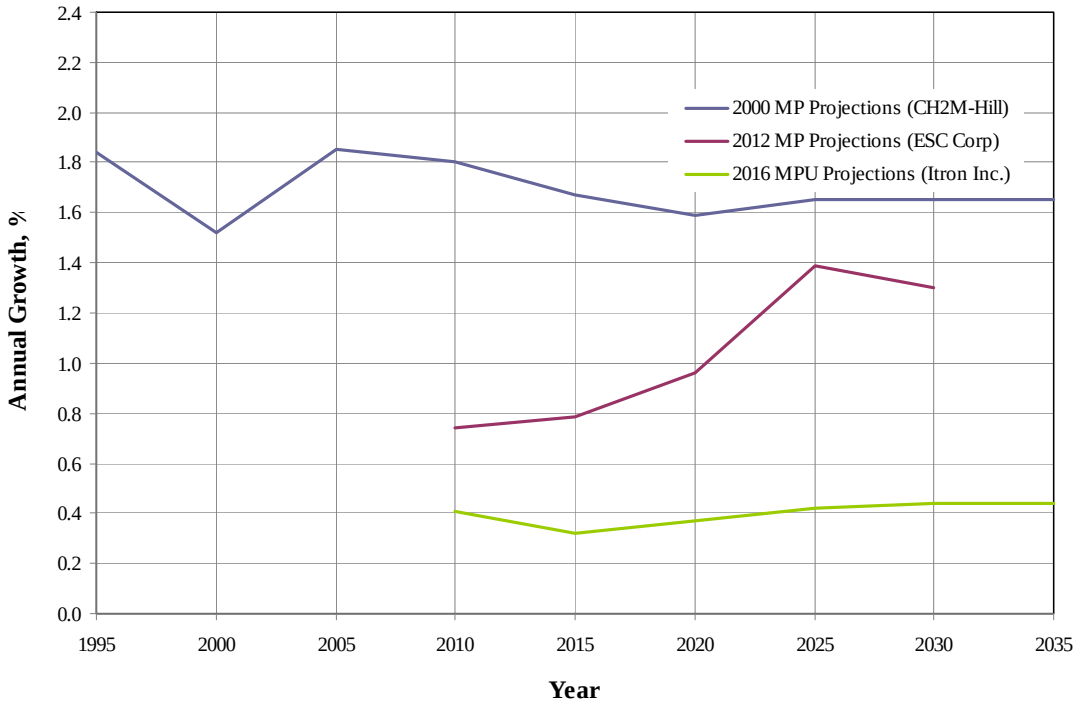
1.3 Recent Developments

In the past four years since publication of the 2012 MP a few items that impact operations of the wastewater utility have changed significantly enough to take into consideration in the current evaluation.

1.3.1 Growth Forecast

In the 2000 Water Master Plan population growth averaged 1.7% per year between 2005 and 2035. By the 2012 MP effort the average from 2010 to 2030 dropped to 1.0% per year and the latest estimates obtained in 2015 only reflect 0.4% per year through 2035. Figure 1-1 presents a comparison of the three growth projection efforts. Details of the new population growth forecast can be found in Appendix A. The change in growth projections impacts the timing of growth related projects. These are all the projected capacity needs in any future planning horizon.

Figure 1-1 Growth Projection Comparison



1.3.2 Operations

Availability and cost of chemicals - Currently the City uses gaseous chlorine at both treatment plants as part of the disinfection process. There is only one distributer of the chemical and if that distributer stops the utility may be forced to look at a different process for disinfection such as ultraviolet light treatment. This would require construction of new treatment plant facilities and have significant cost.

New chemicals - In 2014 and 2015 the State of California declared a drought emergency and implemented mandatory water conservation. When that happened the sewer flows dropped to a degree that created alkalinity and pH challenges for the treatment plants. To mitigate the challenges additional chemicals were required

Chapter 2 - Regulatory Considerations

2.1 Mussels

In 2013 the United States Environmental Protection Agency (USEPA) published final national recommended water quality criteria for the protection of aquatic life from the toxic effects of ammonia in fresh water. The species of concern is freshwater mussels and gill-breathing snails. In April 2014 the City received a letter from the Central Valley Regional Water Quality Control Board providing their understanding of the new limits. The regulations allow for a higher limit on ammonia discharge in the absence of mussels. Until a

survey has been performed the Board will assume the presence of mussels for the purpose of determining the appropriate criteria.

The City of Redding has teamed with other dischargers in the north state to perform a mussel survey to assist in refining the discharge criteria and ammonia limits. Should the survey find mussels present the City could be assigned lower ammonia discharge limits potentially requiring construction of additional treatment facilities at its WWTPs.

2.2 Land application of solids

The City of Redding has currently suspended land application of solids. With construction of new process technologies at the WWTPs solids are being run through a centrifuge and then being hauled to a landfill instead of being sent to drying ponds which then need to be dredged. The utility would like to return to land application at some time in the future.

Chapter 3 - Revised Wastewater Demands

Wastewater demands were adjusted to account for the difference in growth projection between the 2012 Economic Sciences Corp forecast and the 2015 Itron Inc forecast. Figure 1-1 shows the growth projections from three different planning efforts. The current growth forecast is approximately 30-40% of the previous effort. This results in growth related projects being called for at later time frames than those listed in the 2012 Wastewater Utility Master Plan. Table 3.1 shows the new dry weather demand projections.

Table 3.1 Average Dry Weather Demand and Household Equivalent Summary (1)

	Existing (2015)				2020				2025				2035			
Basin	SFR	MF	C/I/Pf	ADWF	SFR	MF	C/I/Pf	ADWF	SFR	MF	C/I/Pf	ADWF	SFR	MF	C/I/Pf	ADWF
Clear Cr	15628	6710	10187	9.8	16034	6782	10304	9.9	16149	6785	10340	10.0	16526	6979	10485	10.2
Stillwater	7901	1969	2157	3.6	8851	2001	2468	4.0	10600	2066	3156	4.7	15156	2259	10600	6.8
Total	23529	8679	12344	13.4	24885	8783	12772	13.9	26749	8851	13496	14.7	31682	9238	21085	18.6

SFR - Single Family Residence, HEs C/I/Pf - Commercial/Industrial/Public Facility, HEs
MF - Multiple Family Residences, HEs ADWF - Average Dry Weather Flow, MGD

(1) Note: This table reflects total demand volume draining into the collection system. Total ADWF from the hydraulic analyisis is likely to be significantly different for two reasons; (1) Sewer demands are applied to the collection system utilizing an hourly diurnal pattern and; (2) Sewer collection pipe networks will have significant dampening or routing effects.

Chapter 4 - Project Status

The following is a listing of project status for projects from the Wastewater Utility Master Plan 2012.

4.1 Existing Needs Projects in 2012

Existing needs projects are pipes, lift stations or treatment plant process that analysis shows are needed under existing wastewater flows. They also include projects from locations that require unusual amounts of maintenance or are excessively difficult to maintain.

4.1.1 Completed projects

- Churn Creek Lift Station Improvements
- Clear Creek WWTP Bid Packages 5,6 & 7
- Stillwater WWTP Phase 1A and 1B
- Solids Handling Facility
- North Market Lift Station (LS-CC-4 and LS-CC-5)

4.1.2 Delayed projects

- Cumberland (P-CC-2) - The Cumberland Drive project was put on hold pending an alternative route to divert sewer from West Side Lift Station through Westridge subdivison. Capacity in the Cumberland pipe would be adequate should the diversion occur.
- Buenaventura Offsite Sewer (P-CC-4) - As with the Cumberland Drive project a significant amount of the Buenaventura Offsite Sewer project would not be necessary if the diversion through Westridge Subdivision occurs. Approximately 50% of the project, the lower 50%, is still considered capacity challenged.
- Westside Lift Station (LS-CC-1) - Westside Lift Station is also expected to be taken out of service if Westridge Subdivison diversion is constructed.
- East Cypress (P-CC-3) The East Cypress project was eliminated from the project list as a result of more detailed analysis. Investigation of as-built drawings discovered that the pipes are actually larger in diameter than what was shown in GIS at the time the model was built. Analysis using the actual pipe diameters revealed that there is no need for increased capacity at this location.
- Canby Bypass Phase 1 (P-CC-6)
- Oasis Road (P-S-1)

4.1.3 Projects In Design/Construction

- Lake Redding Interceptor (P-CC-1) Lake Redding Interceptor is currently approaching the end of the design process and Phase 1 is expected to go to construction within the next year. The project raised constructability concerns regarding the possibility that trenching may need to occur in old dredger tailings.
- West Side Interceptor Phase III (P-CC-7) West Side Interceptor Phase III project crosses Olney Creek and Clear Creek prompting a substantial alignment alternatives analysis to determine the preferred alignment considering cost, environmental, and constructability considerations. The site also has dredger tailing concerns and does not appear to be a candidate for trenchless technology to cross the creeks.
- Mistletoe and Hilltop were combined and are currently under construction.
- Mercury Drive and Boneset Street projects are in the initial steps of design and are expected to be constructed within the next year.
- Enterprise High School is currently being scoped for pipe bursting to a larger diameter in summer 2017.

4.2 Projects listed for 2010-2015

- Bechelli South (P-CC-17) The Bechelli South project is a small project in the intersection of Bechelli Lane and Hartnell Avenue where traffic control will likely be challenging. It is currently being investigated for inclusion in a larger regional pipe replacement project.
- Sunnyhill Lift Station Improvements (LS-CC-24 and LS-CC-25) were dismissed as backup strategy changed to one of hiring a contractor to do bypass pumping should it become necessary.
- Azalea I-5 Crossing was lined and not being considered for replacement.

4.3 Projects listed for 2015-2020

- Lower Sulphur Creek Sewer (P-CC-8) and Upper Sulphur Creek Sewer (P-CC-9) Scheduling of these projects can be moved out to the early pare of the 2025-2035 planning time frame due to the decreased demand projectsions.

4.4 Projects listed for 2020-2030

- Bechelli Lane (P-CC-11) This project can be moved out beyond the planning duration of this addendum due to the decreased growth forecast.
- Riverbend Lift Station (LS-CC-3) The Riverbend lift station analysis showed that it was operating at design capacity under existing conditions in 2012 therefore should remain on schedule for an upgrade.
- Boulder Creek Interceptor Phase III (P-S-4)

4.5 Projects listed for UBO

Projects listed between 2030 and UBO only change with respect to the new planning time frame of this addendum, 2035 to UBO. They are:

- Upper Jenny Creek (P-CC-10)
- Canby Byass (P-CC-12)
- Branstetter (P-CC-13)
- El Reno (P-CC-14)
- Enterprise High School (P-CC-15). Although originally scheduled in the 2030-UBO time frame the 2016 revised analysis shows the Enterprise High School (P-CC-15) project should be a current needs project.
- Locust Lift Station (LS-CC-6)
- Boulder Creek PII (P-S-4)
- Oasis Road (P-S-6)
- Edgewood Drive (P-S-3)
- Baer Road (P-S-2)
- Quartz Hill (P-S-7)

4.6 Maintenance Projects

Maintenance projects are those that arise from locations that are difficult to maintain or requiring excessive maintenance. Because they are not growth related they are all existing needs projects that are scheduled based on the severity of each particular issue. Below are the projects that are currently being designed or constructed:

- Mesa Alley (P-CC-24), San Francisco Drive South (P-CC-22), San Francisco Drive West (P-CC-21) projects were combined and grouped with a pipe replacement project covering the whole neighborhood. The project design is complete and expected to be constructed within the next year.
- Hilltop (P-CC-19) and Mistletoe (P-CC-29) have been combined and are currently being constructed.
- School Street (P-CC-32) and Manzanita Drive (P-CC-25) have been combined along with Enterprise High School (P-CC-15) and are scheduled for construction in summer 2017.
- Clover Creek Interceptor Rehab (P-S-11) was inadequately scoped in the 2012 Plan and ongoing monitoring efforts are being pursued in attempt to refine the scope of the project.

Chapter 5 - Stillwater Creek Service Area

The Wastewater Utility Master Plan 2012 discussed at length strategies for providing wastewater service east of the divide between Clover Creek and Churn Creek drainage basins and Stillwater Creek drainage basin. One of the strategies investigated was to determine the projects and improvements necessary to the existing collection system should wastewater service to Stillwater Creek areas be lifted over the divide. The effort listed and obtained cost estimates for this strategy but did not include cost estimates of the other alternatives, leaving the alternatives analysis for future efforts. Appendix B presents additional cost information including a planning level cost estimate of the original conceptual Stillwater Interceptor.

In summary the Stillwater Interceptor, as originally conceived, has an estimated cost of $109.6-million including the main interceptor, local large interceptors, lift station, design, environmental, right-of-way, and

contingencies. Improvements to the existing system to convey the same volume of wastewater is estimated to be $12.9-million. The difference arises from the ability to utilize excess capacity in some of the existing large interceptors and transferring the cost of the local interceptors to the project proponents.

Chapter 6 - Inflow and Infiltration

The wastewater utility staff has implemented a flow monitoring program which includes 22 flow monitors collecting both dry and wet weather flows. Annual RDI&I reports have been generated for each of the last three winters that include analysis of precipitation and dry and wet weather flows. The reports evaluate the magnitude of I&I relative to a number of different metrics to determine whether the level of I&I is acceptable. The report ranks the monitored areas and makes recommendations for pipe replacement projects to reduce I&I and placement of monitors for the subsequent years monitoring effort. The 2013-14 RDI&I report is included as Appendix C.

Success of the monitoring effort depends on the magnitude of storm events that occur during the monitoring effort. The standard design storm for wastewater collection systems is the 10-year, 24-hour duration storm. Although winter 2015-16 was a normal or slightly above normal precipitation year the prior two years were drought years and no storms occurred that approached the magnitude of the design storm.

In 2012 the wastewater utility replaced 9,596 feet of aging collection system pipe, in 2013 the amount grew to 14,725 feet, and in 2015 replaced 10,041 feet. In addition in the last two years (2014 and 2015) the utility lined 4190 ft and 1172 ft respectively. This totals 52,582 feet of pipe replaced or lined in the last three years.

Chapter 7 - Revised Capital Improvement Plan

7.1 Introduction

The capital improvement plan revision included elimination of the projects that have been completed and rescheduling of projects that may not be needed as soon as originally expected due to the change in population growth forecast. Project scheduling also includes some adjustment to timing to avoid large spikes in construction spending that are difficult to manage from a financial perspective. Statistically, projects that are delayed beyond the date where an SSO is indicated incur a 10 percent per year risk of overflow.

7.2 Project Classification and Cost Estimating

Cost estimates were prepared for each collection system capital project. The cost estimates presented were made without the benefit of detailed engineering data and do not include alternatives analysis. The estimates are based on cost curves, bid tabs for recent City projects, and preliminary estimated quantities for major facility components. The final cost of each project and the resulting budget impacts will depend on actual labor and material costs, competitive market conditions, actual site conditions, final projects scope, implementation schedules, and other variables. Therefore the final project costs will vary from those presented herein, and each project must be evaluated in greater detail prior to making specific financing decisions or establishing project budgets. A cost estimate report is included in Appendix G of the 2012 Master Plan, which was prepared by the engineering consulting firm CH2M Hill Engineers.

To prioritize the recommended modifications and improvements, each facility is ranked to assess the relative value of improvements with respect to overall performance, compliance with regulatory requirements, cost of operation, ease of operation, and other various factors. Specifically, improvements were evaluated against the following criteria: process, reliability, operability, constructability, regulatory considerations, relative cost, and risk. Issues considered under each criteria are summarized in Table 7.1.

Once the projects were ranked for each criteria a value was assigned to each category from 1 to 6 representing the Utility priority for each criteria. This provides a mechanism for projects that are required for regulatory complance or with high potential risk to attain a higher score. Project criteria ranking scores were then multiplied by the criteria values and summed for each project to attain a project score. Projects were then sorted by overall score for each planning time frame to attain a prioritized list. The ranking scale and criteria values are presented in Table 7.2.

Tables 7.3, 7.4, and 7.5 identify the capital improvements, ranking, scoring, and reason for the projects and recommended improvements. Tables 7.6, 7.7 and 7.8 show the cost and cost distribution of each project.

Table 7.1 - Ranking Criteria

Criteria	Issues Considered
Reliability	- Is it Dependable? - Level of redundancy
Operability	- Complexity of operation - Maintenance requirements - Staffing requirements - History of technology - Does it work?
Constructability	- Complexity/ease of construction - Space requirements - Environmental constraints - Political considerations
Regulatory	- Current or pending regulatory requirements dictate undertaking the project
Relative Cost	- Less than $100k - $100k to 500k - Greater than $500k
Risk	- Risk of significant fiscal repercussions if project is deferred or not completed

Table 7.2 Ranking Scale

Criteria	**Value**	Points		
		0	1	2
Process	2	Insignificant	Limited	Significant
Reliability	3	Insignificant	Limited	Significant
Operability	3	Insignificant	Limited	Significant
Constructability	2	Difficult	Limited	Easy
Regulatory	6	Not	Limited	Required
Relative Cost	4	High	Intermediate	Low
Risk	5	Low	Intermediate	High

Table 7.3 - Facility Improvements 2016-2020

Tag No.	Facility Type	Facility Name	Identified Projects	Recommendation	Reason	Project Property Category: Process	Reliability	Operability	Constructability	Regulatory	Relative Cost	Risk	Value Score Product: Process	Reliability	Operability	Constructability	Regulatory	Relative Cost	Risk	Total Score
P-S-1	Sewer Pipe	Oasis Road	Construct 780 feet of 12-inch and 400 feet of 15-inch diameter pipe	Construct/Replace	Capacity	0	1	0	1	2	2	2	0	3	0	2	12	8	10	35
LS-CC-1	Lift Station	Westside Lift Station	Construct larger lift station	Construct larger	Capacity	1	2	0	2	2	0	2	2	6	0	4	12	0	10	34
P-CC-1	Interceptor	Lake Redding Interceptor	Construct 1820 feet of 21-inch, 4790 feet of 24-inch and 950 feet of 27-inch diameter pipe	Construct/Replace	Capacity	0	1	1	2	2	0	2	0	3	3	4	12	0	10	32
TP-CC-1	Treatment Plant	Clear Creek WWTP	Levee Improvements	Construct	Reliability/Regulatory	0	2	1	0	2	1	1	0	6	3	0	12	4	5	30
P-CC-6	Sewer Pipe	Canby Bypass Phase 1	Construct 1210 feet of 18-inch diameter pipe	Construct/Replace	Capacity	0	0	0	1	2	1	2	0	0	0	2	12	4	10	28
P-CC-7	Interceptor	Westside Interceptor Phase III	Construct 3162 feet of 48-inch diameter pipe	Construct/Replace	Capacity	1	0	1	0	2	0	2	2	0	3	0	12	0	10	27
P-CC-2	Sewer Pipe	Cumberland Sewer	Construct 1820 feet of 12-inch diameter pipe	Construct/Replace	Capacity	0	1	0	1	2	1	1	0	3	0	2	12	4	5	26
LS-CC-2	Lift Station	Hartnell LS	Increase Capacity	Improve	Capacity	1	1	0	2	1	0	2	2	3	0	4	6	0	10	25
LS-CC-4	Lift Station	North Market LS	Focused Study on Capacity and Projected Flows	Study	Capacity	1	1	1	2	0	2	1	2	3	3	4	0	8	5	25
LS-CC-11	Lift Station	Hartnell Lift Station	Replace Controls	Replace	Dependability	1	1	2	2	0	2	0	2	3	6	4	0	8	0	23
LS-CC-13	Lift Station	Hartnell Lift Station	Add SCADA Control	Construct	Operation	1	1	2	2	0	2	0	2	3	6	4	0	8	0	23
P-CC-17	Sewer Pipe	Bechelli South	Construct 100 feet of 15-inch diameter pipe	Construct/Replace	Capacity	0	0	0	1	2	2	0	0	0	0	2	12	8	0	22
P-CC-5	Sewer Pipe	Mercury Drive Sewer	Construct 1670 feet of 12-inch diameter pipe	Construct/Replace	Capacity	0	1	0	1	2	1	0	0	3	0	2	12	4	0	21
P-S-8	Sewer Pipe	Patterson Ct	Construct 524 feet of 6-inch diameter pipe	Construct/Replace	Maintenance	0	1	2	2	0	2	0	0	3	6	4	0	8	0	21
P-CC-32	Sewer Pipe	School Street	Replace 1803 feet of 6-inch diameter pipe	Construct/Replace	Maintenance	0	1	2	1	0	2	0	0	3	6	2	0	8	0	19
P-S-9	Sewer Pipe	Boneset Street	Construct 262 feet of 6-inch and 255 feet of 12-inch diameter pipe	Construct/Replace	Maintenance	0	1	2	1	0	2	0	0	3	6	2	0	8	0	19
P-CC-23	Sewer Pipe	Loma Street Alley	Replace 1847 feet of 8-inch diameter pipe	Construct/Replace	Maintenance	0	1	2	2	0	1	0	0	3	6	4	0	4	0	17
P-CC-31	Sewer Pipe	Churn Creek Road	Replace 566 feet of 6-inch diameter pipe	Construct/Replace	Maintenance	0	1	2	2	0	1	0	0	3	6	4	0	4	0	17
P-CC-26	Sewer Pipe	Hallmark Alley	Replace 2403 feet of 6" diameter pipe	Replace	Maintenance	0	1	2	1	0	1	0	0	3	6	2	0	4	0	15
P-CC-27	Sewer Pipe	Redbud Alley	Replace 1174 feet of 6" diameter pipe	Replace	Maintenance	0	1	2	1	0	1	0	0	3	6	2	0	4	0	15
LS-CC-12	Lift Station	Hartnell Lift Station	Enclosure	Construct	Longevity	0	1	0	2	0	2	0	0	3	0	4	0	8	0	15
LS-CC-15	Lift Station	Locust LS	Replace LS	Construct	Safety/Dependability	1	1	1	0	0	0	1	2	3	3	0	0	0	5	13
P-CC-28	Sewer Pipe	Woodacre Drive	Replace 1375 feet of 8-inch diameter pipe	Construct/Replace	Maintenance	0	0	2	1	0	1	0	0	0	6	2	0	4	0	12

Table 7.4 - Facility Improvements 2021-2025

Tag No.	Facility Type	Facility Name	Identified Projects	Recommendation	Reason	Project Property Category: Process	Reliability	Operability	Constructability	Regulatory	Relative Cost	Risk	Value Score Product: Process	Reliability	Operability	Constructability	Regulatory	Relative Cost	Risk	Total Score
P-CC-8	Sewer Pipe	Sulphur Creek P1	630 feet of 18-inch and 2110 feet of 21-inch diameter pipe	Construct	Capacity	0	1	0	1	2	2	2	0	3	0	2	12	8	10	35
P-CC-9	Sewer Pipe	Sulphur Creek P2	440 feet of 12-inch and 2250 feet of 15-inch diameter pipe	Construct	Capacity	0	1	0	1	2	2	2	0	3	0	2	12	8	10	35
LS-CC-8	Lift Station	Cheryl Lift Station	AC Drives	Construct	Capacity	0	1	1	2	0	2	0	0	3	3	4	0	8	0	18
P-CC-4	Interceptor	Buenaventura Sewer	Construct 4400 feet of 12-inch, 3560 feet of 15-inch and 2970 feet of 18-inch diameter pipe	Construct/Replace	Capacity	0	0	0	0	2	0	0	0	0	0	0	12	0	0	12

Table 7.5 - Facility Improvements 2026-2035

Tag No.	Facility Type	Facility Name	Identified Projects	Recommendation	Reason	Project Property Category: Process	Reliability	Operability	Constructability	Regulatory	Relative Cost	Risk	Value Score Product: Process	Reliability	Operability	Constructability	Regulatory	Relative Cost	Risk	Total Score
TP-S-1	Treatment Plant	Stillwater WWTP	Numerous improvements contained in Facilities Plan	Construct	Capacity/Operation	2	1	2	1	2	0	1	4	3	6	2	12	0	5	32
TP-CC-3	Treatment Plant	Clear Creek WWTP	Holding Pond Upgrades	Construct	Reliability/Regulatory	1	1	1	0	2	1	1	2	3	3	0	12	4	5	29
P-S-5	Sewer Pipe	Boulder Creek PIII	2460 feet of 10-inch, 2360 feet of 12-inch and 2760 feet of 15-inch diameter pipe	Construct	Capacity	0	1	0	0	2	0	2	0	3	0	0	12	0	10	25
LS-CC-3	Lift Station	Riverbend LS	Increase Capacity	Improve	Capacity	0	0	0	2	0	0	1	0	0	0	4	0	0	5	9

Table 7.6 - Facility Improvements 2016-2020 (2012 Cost Estimates Escalated to 2015 Dollars)

Tag No.	Facility Type	Facility Name	Identified Projects	Recommendation	Reason	Cost Estimate (1)	Total Score	Funding Split Rates, %	Funding Split Fees, %	Amounts Rates	Amounts Fees
P-S-1	Sewer Pipe	Oasis Road	Construct 780 feet of 12-inch and 400 feet of 15-inch diameter pipe	Construct/Replace	Capacity	$420,606	35	34	66	$143,006	$277,600
LS-CC-1	Lift Station	Westside Lift Station	Construct larger lift station	Construct larger	Capacity	$485,481	34	100	0	$485,481	$0
P-CC-1	Interceptor	Lake Redding Interceptor	Construct 1820 feet of 21-inch, 4790 feet of 24-inch and 950 feet of 27-inch diameter pipe	Construct/Replace	Capacity	$5,298,125	32	39	61	$2,066,269	$3,231,856
TP-CC-1	Treatment Plant	Clear Creek WWTP	Levee Improvements	Construct	Reliability/Regulatory	$1,957,063	30	100	0	$1,957,063	$0
P-CC-6	Sewer Bypass	Canby Bypass Phase 1	Construct 1210 feet of 18-inch diameter pipe	Construct/Replace	Capacity	$475,750	28	100	0	$475,750	$0
P-CC-7	Interceptor	Westside Interceptor Phase III	Construct 3162 feet of 48-inch diameter pipe	Construct/Replace	Capacity	$2,703,125	27	0	100	$0	$2,703,125
P-CC-2	Sewer Pipe	Cumberland Sewer	Construct 1820 feet of 12-inch diameter pipe	Construct/Replace	Capacity	$595,769	26	100	0	$595,769	$0
LS-CC-2	Lift Station	Hartnell LS	Increase Capacity	Improve	Capacity	$126,506	25	0	100	$0	$126,506
LS-CC-4	Lift Station	North Market LS	Focused Study on Capacity and Projected Flows	Study	Capacity	$127,588	25	6	94	$7,655	$119,932
LS-CC-11, 12, 13	Lift Station	Hartnell Lift Station	Replace Controls, add SCADA, add enclosure	Replace	Dependability	$126,506	23	100	0	$126,506	$0
P-CC-11,17	Sewer Pipe	Bechelli South	Construct 100 feet of 15-inch diameter pipe	Construct/Replace	Capacity	$136,238	22	100	0	$136,238	$0
P-CC-5	Sewer Pipe	Mercury Drive Sewer	Construct 1670 feet of 12-inch diameter pipe	Construct/Replace	Capacity	$556,844	21	100	0	$556,844	$0
P-S-8	Sewer Pipe	Patterson Ct	Construct 524 feet of 6-inch diameter pipe	Construct/Replace	Maintenance	$229,225	21	100	0	$229,225	$0
P-CC-32	Sewer Pipe	School Street	Replace 1803 feet of 6-inch diameter pipe	Construct/Replace	Maintenance	$511,431	19	100	0	$511,431	$0
P-S-9	Sewer Pipe	Boneset Street	Construct 262 feet of 6-inch and 255 feet of 12-inch diameter pipe	Construct/Replace	Maintenance	$169,756	19	100	0	$169,756	$0
P-CC-23	Sewer Pipe	Loma Street Alley	Replace 1847 feet of 8-inch diameter pipe	Construct/Replace	Maintenance	$520,081	17	100	0	$520,081	$0
P-CC-31	Sewer Pipe	Churn Creek Road	Replace 566 feet of 6-inch diameter pipe	Construct/Replace	Maintenance	$187,056	17	100	0	$187,056	$0
P-CC-26	Sewer Pipe	Hallmark Alley	Replace 2403 feet of 6" diameter pipe	Replace	Maintenance	$661,725	15	100	0	$661,725	$0
P-CC-27	Sewer Pipe	Redbud Alley	Replace 1174 feet of 6" diameter pipe	Replace	Maintenance	$323,294	15	100	0	$323,294	$0
LS-CC-15	Lift Station	Locust LS	Replace LS	Construct	Safety/Dependability	$535,219	13	100	0	$535,219	$0
P-CC-28	Sewer Pipe	Woodacre Drive	Replace 1375 feet of 8-inch diameter pipe	Construct/Replace	Maintenance	$444,394	12	100	0	$444,394	$0
					Total:	$16,591,781				$10,132,761	$6,459,020

(1) 2015 dollars at CCI 10034

Table 7.7 - Facility Improvements 2021-2025 (2012 Cost Estimates Escalated to 2015 Dollars)

Tag No.	Facility Type	Facility Name	Identified Projects	Recommendation	Reason	Cost Estimate (1)	Total Score	Funding Split Rates, %	Funding Split Fees, %	Amounts Rates	Amounts Fees
P-CC-8, 9	Sewer Pipe	Sulphur Creek	630 feet of 18-inch and 2110 feet of 21-inch diameter pipe 440 feet of 12-inch and 2250 feet of 15-inch diameter pipe	Construct	Capacity	$2,241,431	35	75	25	$1,681,073	$560,358
LS-CC-7, 8	Lift Station	Cheryl Lift Station	Shade Structure, add AC Drives	Construct	Longevity	$150,294	18	0	100	$0	$150,294
TP-CC-2	Treatment Plant	Clear Creek WWTP Pond	Line Pond 2	Construct	Capacity/Regulatory	$2,552,831	23	75	25	$1,914,623	$638,208
P-CC-4	Interceptor	Buenaventura Sewer	Construct 4400 feet of 12-inch, 3560 feet of 15-inch and 2970 feet of 18-inch diameter pipe	Construct/Replace	Capacity	$4,115,238	12	33	67	$1,358,028	$2,757,209
					Total:	$9,059,794				$4,953,725	$4,106,069

(1) 2015 dollars at CCI 10034

Table 7.8 - Facility Improvements 2026-2035 (2012 Cost Estimates Escalated to 2015 Dollars)

Tag No.	Facility Type	Facility Name	Identified Projects	Recommendation	Reason	Cost Estimate (1)	Total Score	Funding Split Rates, %	Funding Split Fees, %	Amounts Rates	Amounts Fees
TP-S-1	Treatment Plant	Stillwater WWTP	Numerous improvements contained in Facilities Plan	Construct	Capacity/Operation	$19,360,863	32	75	25	$14,520,647	$4,840,216
TP-CC-3	Treatment Plant	Clear Creek WWTP	Holding Pond Upgrades	Construct	Reliability/Regulatory	$5,024,569	29	75	25	$3,768,427	$1,256,142
P-S-5	Sewer Pipe	Boulder Creek PIII	2460 feet of 10-inch, 2360 feet of 12-inch and 2760 feet of 15-inch diameter pipe	Construct	Capacity	$3,139,950	25	75	25	$2,354,963	$784,988
TP-CC-3	Treatment Plant	Clear Creek WWTP Pond	Line Pond 4	Construct	Capacity/Regulatory	$2,471,738	23	75	25	$1,853,803	$617,934
					Total:	$29,997,119				$22,497,839	$7,499,280

(1) 2015 dollars at CCI 10034

Table 7.9 - Capital Improvement Plan (Projects as Programmed and Escalated to Programmed Year Cost)

		Cost Split		Cost (1)		
Year	Improvement	Rates	Fees	Rates	Fees	Total
2016-2017	Programmatic Pipe Replacement Elements	100%		$1,819,810		$1,819,810
	Lift Station Improvements	100%		$234,120		$234,120
	I/I Reduction	100%		$1,170,600		$1,170,600
	Manzanita Drive	100%		$124,200		$124,200
	East Cypress Sewer	100%		$269,200		$269,200
	Canby Bypass Phase 1	100%		$515,070		$515,070
	Loma Street Alley	100%		$563,060		$563,060
	Lake Redding Interceptor	91%	9%	$2,275,000	$225,000	$2,500,000
	Oasis Road	34%	66%	$140,859	$273,431	$414,290
	Churn Creek Road	100%		$202,520		$202,520
			Totals:	$7,314,439	$498,431	$7,812,870
2017-2018	Programmatic Pipe Replacement Elements	100%		$1,877,890		$1,877,890
	I/I Reduction	100%		$1,206,890		$1,206,890
	Lift Station Improvements	100%		$241,380		$241,380
	Lake Redding Interceptor P1	91%	9%	$2,275,000	$225,000	$2,500,000
	Lake Redding Interceptor P2	91%	9%	$1,137,500	$112,500	$1,250,000
	Cumberland Sewer	100%		$665,610		$665,610
	Hartnell LS	0%	100%		$141,340	$141,340
	North Market LS	6%	94%	$8,553	$133,997	$142,550
	Hallmark Alley	100%		$739,300		$739,300
	Redbud Alley	100%		$361,200		$361,200
			Totals:	$8,513,323	$612,837	$9,126,160
2018-2019	Programmatic Pipe Replacement Elements	100%		$4,411,100	$0	$4,411,100
	I/I Reduction	100%		$1,244,310		$1,244,310
	Lift Station Improvements	100%		$248,870		$248,870
	Lake Redding Interceptor P2	91%	9%	$1,137,500	$112,500	$1,250,000
	Bechelli South	100%		$157,090		$157,090
	Woodacre Drive	100%		$512,400		$512,400
	Patterson Ct	100%		$264,300		$264,300
			Totals:	$7,975,570	$112,500	$8,088,070
2019-2020	Programmatic Pipe Replacement Elements	100%		$5,902,260		$5,902,260
	I/I Reduction	100%		$1,282,890		$1,282,890
	Lift Station Improvements	100%		$256,590		$256,590
	Mercury Drive Sewer	100%		$662,600		$662,600
	Azalea I-5 Crossing	100%		$728,220		$728,220
			Totals:	$8,832,560	$0	$8,832,560
2020-2021	Programmatic Pipe Replacement Elements	100%		$7,789,450		$7,789,450
	I/I Reduction	100%		$1,322,660		$1,322,660
	Lift Station Improvements	100%		$264,550		$264,550
	Westside Interceptor PIII		100%	$0	$2,363,000	$2,363,000
			Totals:	$9,376,660	$2,363,000	$11,739,660
2021-2022	Programmatic Pipe Replacement Elements	100%		$8,084,320		$8,084,320
	I/I Reduction	100%		$1,363,670		$1,363,670
	Lift Station Improvements	100%		$272,760		$272,760
	Westside Interceptor PIII		100%		$2,363,000	$2,363,000
	Cheryl Lane Lift Station		100%		$190,460	$190,460
			Totals:	$9,720,750	$2,553,460	$12,274,210

Year	Improvement	Cost Split		Cost (1)		
		Rates	Fees	Rates	Fees	Total
2022-2023	Programmatic Pipe Replacement Elements	100%		$8,442,800		$8,442,800
	I/I Reduction	100%		$1,405,950		$1,405,950
	Lift Station Improvements	100%		$281,220		$281,220
	Sulphur Creek Interceptor		100%		$2,931,430	$2,931,430
			Totals:	$10,129,970	$2,931,430	$13,061,400
2023-2024	Programmatic Pipe Replacement Elements	100%		$8,879,590		$8,879,590
	I/I Reduction	100%		$1,405,950		$1,405,950
	Lift Station Improvements	100%		$351,520		$351,520
	Buenaventura Sewer	94%	6%	$2,375,201	$151,609	$2,526,810
	Clear Creek WWTP Pond Upgrades	75%	25%	$1,258,646	$419,549	$1,678,195
			Totals:	$14,270,908	$571,157	$14,842,065
2024-2025	Programmatic Pipe Replacement Elements	100%		$9,420,130		$9,420,130
	I/I Reduction	100%		$1,494,480		$1,494,480
	Lift Station Improvements	100%		$298,930		$298,930
	Buenaventura Sewer	94%	6%	$2,451,050	$156,450	$2,607,500
	Clear Creek WWTP Pond Upgrades	75%	25%	$1,298,925	$432,975	$1,731,900
			Totals:	$14,963,515	$589,425	$15,552,940
2025-2026	Programmatic Pipe Replacement Elements	100%		$9,618,060		$9,618,060
	I/I Reduction	100%		$1,540,810		$1,540,810
	Lift Station Improvements	100%		$308,200		$308,200
	Clear Creek WWTP Pond Upgrades	75%	25%	$1,340,498	$446,833	$1,787,330
			Totals:	$12,807,568	$446,833	$13,254,400
2026-2027	Programmatic Pipe Replacement Elements	100%		$9,778,260		$9,778,260
	I/I Reduction	100%		$1,588,580		$1,588,580
	Lift Station Improvements	100%		$317,760		$317,760
	Clear Creek WWTP Pond Upgrades	75%	25%	$1,383,450	$461,150	$1,844,600
			Totals:	$13,068,050	$461,150	$13,529,200
2027-2028	Programmatic Pipe Replacement Elements	100%		$10,091,020		$10,091,020
	I/I Reduction	100%		$1,637,830		$1,637,830
	Lift Station Improvements	100%		$327,620		$327,620
	Stillwater WWTP - Expansion 1C	75%	25%	$5,090,048	$1,696,683	$6,786,730
			Totals:	$17,146,518	$1,696,683	$18,843,200
2028-2029	Programmatic Pipe Replacement Elements	100%		$10,414,090		$10,414,090
	I/I Reduction	100%		$1,688,610		$1,688,610
	Lift Station Improvements	100%		$327,620		$327,620
	Stillwater WWTP- Expansion 1C	75%	25%	$5,253,023	$1,751,008	$7,004,030
	Boulder Creek Interceptor PIII	75%	25%	$1,860,345	$620,115	$2,480,460
			Totals:	$19,543,688	$2,371,123	$21,914,810
2029-2030	Programmatic Pipe Replacement Elements	100%		$10,746,990	$0	$10,746,990
	I/I Reduction	100%		$1,740,960	$0	$1,740,960
	Lift Station Improvements	100%		$348,260	$0	$348,260
	Stillwater WWTP- Expansion 1C	75%	25%	$5,420,918	$1,806,973	$7,227,890
	Boulder Creek Interceptor PIII	75%	25%	$1,919,798	$639,933	$2,559,730
			Totals:	$20,176,925	$2,446,905	$22,623,830

(1) Costs are escalated utilizing the 10-year average CCI to the date of construction

Chapter 8 - Financial Impacts of the Capital Improvement Plan

8.1 Background

The impacts of this new 10- and 20-year CIP on the existing wastewater rates and impact fee accounts was evaluated to determine what changes may be required to adequately fund the utility. The following discussion summarizes the impacts of the CIP on utility finances and reviews the methodology and details for service charge and connection fee evaluations. Recommendations will follow as the product of a cost of service study that will be prepared under contract by a consultant based on the findings of this Master Plan.

The current fee and rate schedules are the result of a report generated by the NBS from 2012 as a result of the Master Planning effort concluding that year. New cost of service and rate studies are being prepared by NBS concurrent with this effort. In consideration of the pending cost of service study, this report will examine the fiscal needs of the utility, including the new capital improvement plan, relative to the utility revenue but will not explore funding alternatives or make recommendations regarding funding mechanisms.

8.2 General Analysis

The following general financial evaluation provides a framework for integrating the CIP projects into the financial analysis.

Analysis of the finances includes the following assumptions:

- Master Plan growth rate projections. Details of the Master Plan growth rate projections can be found in Chapter 3 and Appendix A. Annual growth rates range from 0.32 to 0.44% per year

- CCI escalation of cost of all projects. Cost estimates were prepared in 2012 dollars then escalated by an annual increase of 3.10% to the year the project is scheduled for completion.

- Impact fees increasing at an annual rate of 3.10% starting in 2016-17 to match the CCI

- There are additional Utility budget divisions that set aside various components of the budget for specific purposes if examined at a high enough level of detail. For instance there is an account for rolling stock with interest on the balance that is a line item on revenue. In this document all such accounts were re-combined into either fee or rate accounts for the purpose of identifying potential overall budget challenges.

Base Scenario: The Base Scenario analyzes the budgets using only currently approved increases in Rates and Fees. The only approved increases on the record are the inflation increases on Impact Fees currently at 3.10% per year.

Scenario 1 Inflation: This scenario includes inflation increases added to the Rates as well as Impact Fees.

Scenario 2 Inflation Plus:
Increases Impact Fees for inflation and Rates enough to maintain the cash reserve required for loan security.

Scenario 3 Inflation Plus with Transfer:
This scenario is the same as Scenario 2 except Rate cash is utilized to supplement the Impact Fee account.

8.3 Summary of Findings

Figures 8-1 and 8-2 show the basic balance accounting for the Utility through 2029-30.

A short summary of the findings of the financial analysis prepared with this Master Plan are as follows:

1. Under the current fee schedule, the Impact Fee account is depleted by the end of fiscal year 2021-22.

2. Under the current service rates the rate account will drop below zero in 2019-20.

3. Risks associated with maintaining the current fee and rate schedule are:

- Pipe replacement schedule will not keep up with expiring pipe resulting in an increase in sewer pipe failure
- Treatment plant improvements may not keep up with the regulatory requirements resulting in regulatory actions potentially including fines.
- Delay in construction of facilities necessary to prevent potential SSOs thereby increasing risk of additional regulatory actions.
- Oversizing of replacement pipes to account for potential future development would decrease or be eliminated.

4. The high level analysis revealed that if rates alone are used to keep the Utility balance from dropping below zero, annual increases will need to be implemented ranging from approximately 4.0% to 2.0 % starting with 4.0% in 2017-18.

Although the Cost of Service Study will ultimately make recommendations to resolve the deficit issue, for the purpose of gaining an order of magnitude understanding of the budget gap, a high level analysis was performed to determine what increases in rates would be necessary to fund the utility. Two approaches were applied in this effort to attempt to help mitigate and understand the magnitude of the budget gap, eliminating or delaying projects, and raising the rates.

Unfortunately, the analysis to determine the required projects to maintain the existing level of service and prevent potential SSOs was performed with budget constraint as a criteria so if a project is not necessary it was not listed. After evaluation of the risks associated, numerous projects were delayed beyond the recommended planning horizon. Details and discussion of the risks of delay for each project are discussed in Chapter 7 - Capital Improvement Plan. However, the delay of a project does not necessarily alter the budget deficit other than to help prevent unusually large demands on revenue in a few years.

Figure 8-1 Rate Account End of Year Balance

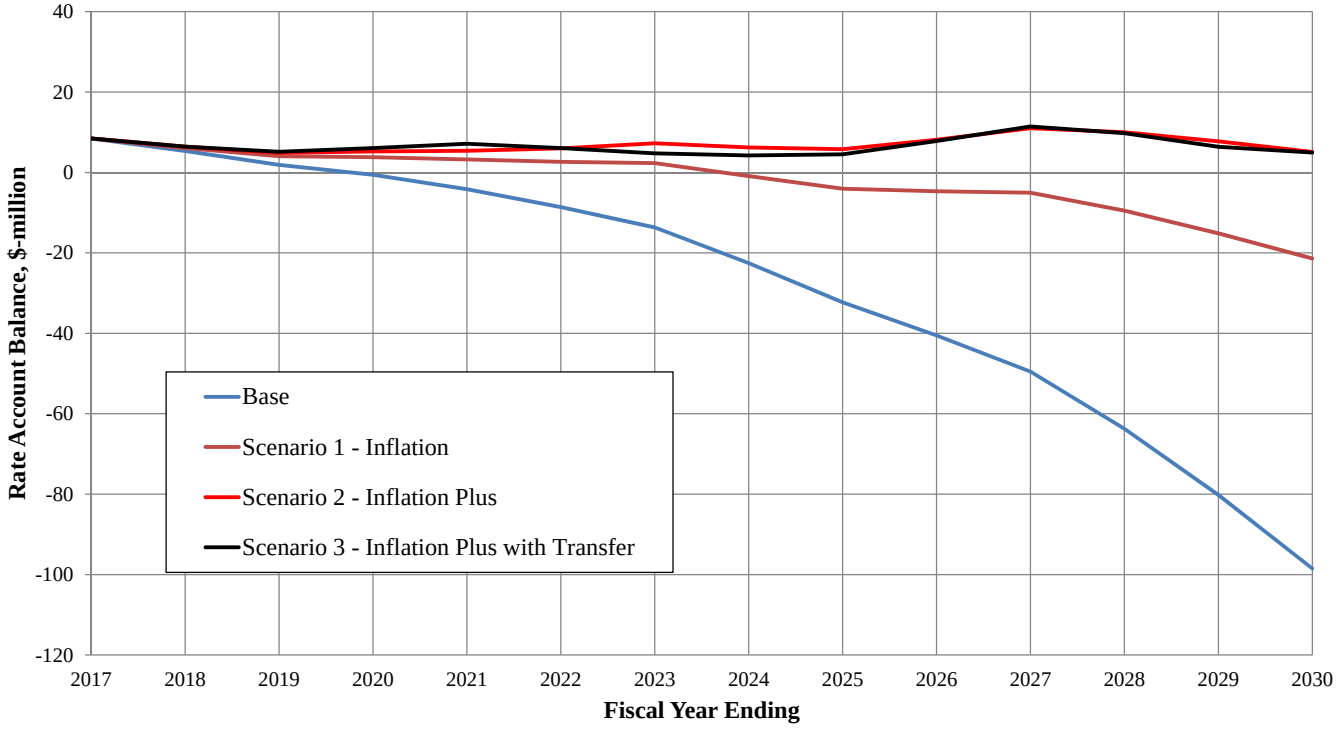
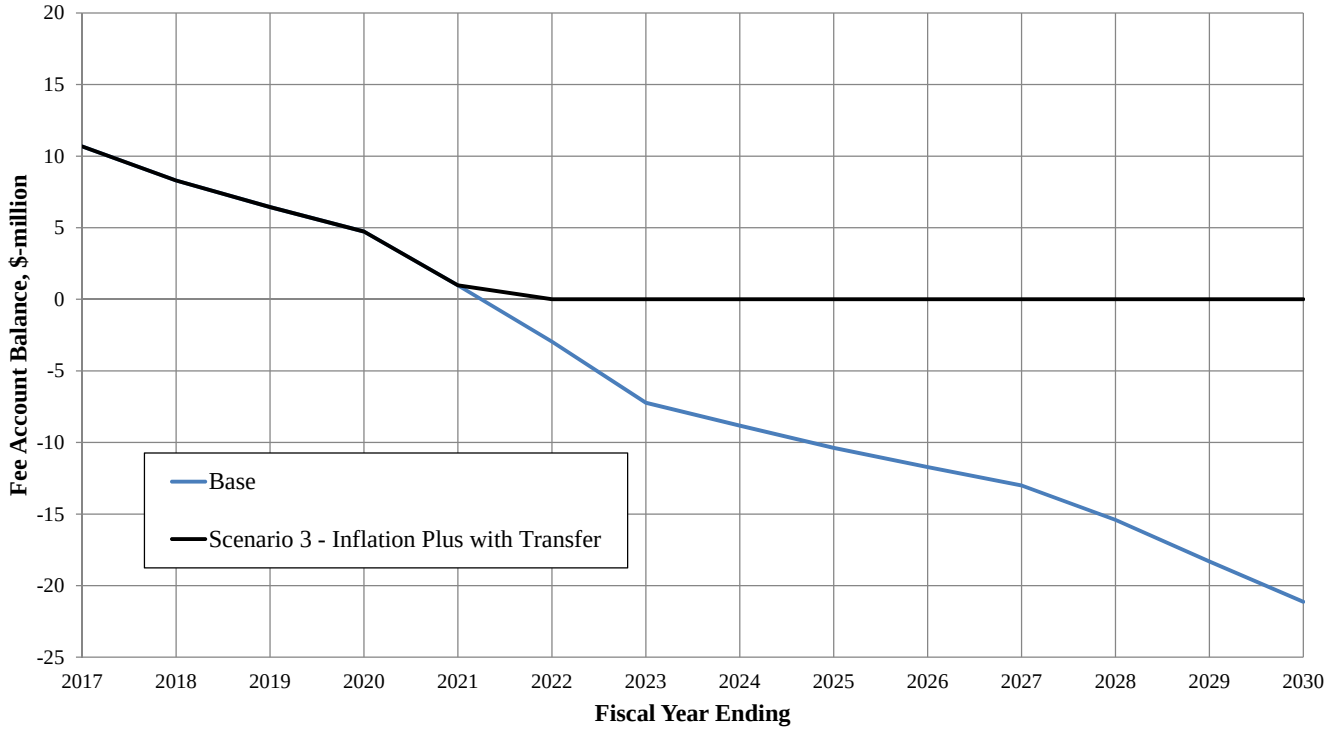


Figure 8-2 Fee Account End of Year Balance



APPENDIX A - City of Redding Growth Forecast

CITY OF REDDING
POPULATION FORECAST
2015 FORECAST

Year	Base	High	Low
1982	45,059	45,059	45,059
1983	46,758	46,758	46,758
1984	48,502	48,502	48,502
1985	50,385	50,385	50,385
1986	52,641	52,641	52,641
1987	55,307	55,307	55,307
1988	58,650	58,650	58,650
1989	62,555	62,555	62,555
1990	66,950	66,950	66,950
1991	70,700	70,700	70,700
1992	73,350	73,350	73,350
1993	75,300	75,300	75,300
1994	76,450	76,450	76,450
1995	77,350	77,350	77,350
1996	78,150	78,150	78,150
1997	78,950	78,950	78,950
1998	79,650	79,650	79,650
1999	80,383	80,383	80,383
2000	81,742	81,742	81,742
2001	83,525	83,525	83,525
2002	84,990	84,990	84,990
2003	86,010	86,010	86,010
2004	86,811	86,811	86,811
2005	87,407	87,407	87,407
2006	88,003	88,003	88,003
2007	88,621	88,621	88,621
2008	89,121	89,121	89,121
2009	89,583	89,583	89,583
2010	89,861	89,861	89,861
2011	90,196	90,196	90,196
2012	90,848	90,848	90,848
2013	91,207	91,207	91,207
2014	91,471	91,498	91,429
2015	91,725	91,780	91,642
2016	91,996	92,090	91,855
2017	92,282	92,427	92,064
2018	92,577	92,785	92,265
2019	92,881	93,164	92,456
2020	93,194	93,565	92,639
2021	93,516	93,988	92,811
2022	93,846	94,432	92,974
2023	94,186	94,900	93,127
2024	94,536	95,391	93,271
2025	94,897	95,907	93,406
2026	95,270	96,450	93,534
2027	95,656	97,020	93,655
2028	96,056	97,621	93,770
2029	96,472	98,252	93,880
2030	96,906	98,918	93,988

CITY OF REDDING
POPULATION FORECAST
2015 FORECAST
Percent Change

Year	Base Case	High Growth	Low Growth
1982	6.69	6.69	6.69
1983	3.77	3.77	3.77
1984	3.73	3.73	3.73
1985	3.88	3.88	3.88
1986	4.48	4.48	4.48
1987	5.07	5.07	5.07
1988	6.04	6.04	6.04
1989	6.66	6.66	6.66
1990	7.03	7.03	7.03
1991	5.6	5.6	5.6
1992	3.75	3.75	3.75
1993	2.66	2.66	2.66
1994	1.53	1.53	1.53
1995	1.18	1.18	1.18
1996	1.03	1.03	1.03
1997	1.02	1.02	1.02
1998	0.89	0.89	0.89
1999	1.13	1.13	1.13
2000	1.69	1.69	1.69
2001	2.18	2.18	2.18
2002	1.75	1.75	1.75
2003	1.2	1.2	1.2
2004	0.93	0.93	0.93
2005	0.69	0.69	0.69
2006	0.68	0.68	0.68
2007	0.7	0.7	0.7
2008	0.56	0.56	0.56
2009	0.52	0.52	0.52
2010	0.31	0.31	0.31
2011	0.37	0.37	0.37
2012	0.72	0.72	0.72
2013	0.4	0.4	0.4
2014	0.29	0.32	0.24
2015	0.29	0.32	0.24
2016	0.28	0.31	0.23
2017	0.3	0.34	0.23
2018	0.31	0.37	0.23
2019	0.32	0.39	0.22
2020	0.33	0.41	0.21
2021	0.34	0.43	0.2
2022	0.35	0.45	0.19
2023	0.35	0.47	0.18
2024	0.36	0.5	0.16
2025	0.37	0.52	0.15
2026	0.38	0.54	0.15
2027	0.39	0.57	0.14
2028	0.41	0.59	0.13
2029	0.42	0.62	0.12
2030	0.43	0.65	0.12

APPENDIX B - Stillwater Interceptor and Alternatives

B.1 - Stillwater Interceptor

Section 6.7 of the 2012 Master Plan summarizes the history of evaluating providing sewer service to the Stillwater Creek drainage basin. It also includes evaluation of improvements necessary for the possibility of constructing lift stations to transfer the sewer to the existing collection system and a tally of the additional household equivalent demands expected. The cost of the improvements was estimated however not included in the report pending the decision to adopt that strategy and abandon the former Stillwater Interceptor concept.

The geographic extent of the conceptual Stillwater Interceptor was from Tierra Oaks to Stillwater WWTP. In the early 2000s Stillwater Business Park was constructed without including the large diameter interceptor that would be necessary to complete the original plan. There are two alternatives for closing that gap, to construct through the Business Park on the west floodplain of the Creek or lift at Rancho Road to Airport Road and construct the remainder in Airport Road. Cost estimates were prepared for the latter alternative. The difference being the cost of the lift station construction.

The interceptor length would be 14.17 miles. Based on the cost of construction of the Phase 1 Boulder Creek Interceptor and escalation from 2012 to 2016 using the CCI the cost for the large diameter single pipe interceptor would be $41.76-million including, construction contingency, engineering, environmental and 10% for right of way. Figure B-1 shows the extent and approximate location of the conceptual Stillwater Inteceptor.

Because the geography of Stillwater drainage basin is branched a single large interceptor will not serve a significant population so large diameter side interceptors are also expected. Figure B-2 shows an approximation of the large diameter side interceptors necessary to provide more complete service to the area. These “local interceptors” total 20.44 miles at a cost estimate of $60.22-million.

The lift station and force main at Rancho Road was estimated at $7.62-million bringing the total cost to $109.60-million.

B.2 - Community Outreach

As part of the 2012 Master Plan effort staff conducted numerous workshops to obtain community feedback and guidance on what parts of the community had the highest probability of growth. One of the specific topics discussed was sewer service to Stillwater Creek Drainage. Details of the discussion can be found in Appendix B of the 2012 Master Plan and included in the following:

B.2.1 - Stillwater North

1. The north area of Stillwater Creek Drainage (North of HWY 299) would not likely see significant development prior to 2030 and even after that most of the area would not need sewer service due to the existing large lot development that exists today. Figure B-3 shows the three Stillwater sub-areas.

2. Shasta College may need to be annexed and served eventually. At that time some development may piggyback on whatever sewer system is constructed to serve the college.
3. Areas closer to or within City Limits, within the primary General Plan boundary may want to develop prior to 2030.

Recommendations for service to this area were:
- Areas within City Limits should be allowed to pump over to the existing collection system and improve local pipes to convey to Churn Creek Interceptor or Clover Creek Interceptor at the developers expense.
- Areas north of Tierra Oaks LS and force main shall drain to Tierra Oaks LS and such development shall provide analysis of their fair share of the necessary lift station improvements. Such development should not be allowed to occur prior to necessary lift station improvements being constructed.

More recent and detailed evaluation of the use of Tierra Oaks Lift Station has determined that it was designed for the specific number of household equivalents that developers have entitlement to. In addition recent testing of the capacity of the lift station has found that its capability has decreased significantly since construction. Between the two any additional entitlement for sewer service utilizing the lift station should be predicated upon construction of improvements to the facility.

B.2.2 - Middle Stillwater

The middle Stillwater area was described as the area between Old Alturas on the south to HWY 299 on the North.

- The area consists primarily of McConnell Foundation properties being held in reserve for potential future university locations. If such property were to develop it would be a fairly lengthy process not likely to result in significant demand for many years, probably beyond 2030.
- Area within City limits could be pumped to Churn Creek interceptor with improvements to the existing system, lift station, force main and local improvements to be the burden of the developer.
- Area between City limits and Primary growth boundary would require additional lifting.
- The Nash Ranch was recently purchased by a local developer. Consensus on when further development of that property may occur resulted in placing it somewhere between 2020 and 2030. No additional information has come forward since the 2012 effort.

B.2.3 - Stillwater South

The Stillwater South area consists of all area south of Old Alturas with the exception of Stillwater Business Park.

Discussion with Shasta County officials indicated they believe that development of area east of Stillwater Creek will not happen at high enough density to call for sewer due to transportation limitations. Stillwater BP conservation easement prohibits extension of the road through the Business Park beyond the park boundaries. Stillwater Road from the north is undeveloped and may even be a private road. It is believed that property owners would not cooperate with expansion of the road to promote higher density development of nearby properties.

The remaining area includes primary growth area between Stillwater Creek and the drainage divide to the Clover Creek Interceptor. Part of this area is already within the Airport Road Sewer Assessment district and the remainder is not enough to consider feasible for funding construction of a public lift station.

B.3 - Local Improvements

The conclusion of the Stillwater Creek Dranage area sewer service investigation was that the existing collection system can be improved to convey the additional sewer flow at a far smaller cost than construction of the conceptual Stillwater Interceptor. The local improvements necessary to convey sewer expected from development of the remaining areas within the current City Limits were estimated to cost $6.04-million (2016 dollars). Cost estimate for improvements to Churn Creek and Tierra Oaks lift stations were $5.15-million and $1.75-million respectively. Improvements to the Wastewater Treatment Plant are estimated to be $50.67-million, however only 14.8% of the increased demand is expected to arise from Stillwater Creek Drainage so only $7.5-million is applicable to this discussion. Also the treatment plant improvements would be necessary regardless of whether the collection system is the Stillwater Interceptor or improved existing collection system so will be omitted from the total for comparison to the prior section's cost of the Interceptor. The estimated total cost of improvements to the existing system to convey sewer pumped to the major interceptors from Stillwater Creek Drainage Area is $12.94-million. This is predicated on developments paying for the necessary improvements to collect and deliver the sewer flow to the existing major interceptors (Churn Creek and Clover Creek) at their own expense.

The conclusion is that improvement of the existing system is a small fraction of the cost of construction of the Stillwater Interceptor, $12.94-million vs $109.60-million. The difference arises from the ability to utilize excess capacity in some of the existing large interceptors and transferring the cost of the local interceptors to the project proponents.

APPENDIX C - 2013-14 Rain Driven Inflow and Infiltration Report

Rainfall Derived Infiltration Inflow (RDII) Report

Prepared for the

City of Redding Wastewater Utility

By

City of Redding Public Utilities Department

Engineering Division

July 2014

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Appendix A - Detailed Data

Abbreviations and Acronyms

Acronym	Meaning
ADDF	Average daily dry weather flow that includes both wastewater production (WWP) and base infiltration (BI)
BI	Base Infiltration – the groundwater component of ADF
CCTV	Closed Circuit Television
CSO	Combined Sewer Overflow
CEPA	California Environmental Protection Agency
GPDIM	Gallons per day per inch-mile
GWI	Ground Water Infiltration
I/I	Infiltration and Inflow
NOAA	National Oceanic and Atmospheric Administration
RDII	Rain Derived infiltration and Inflow
SSES	Sewer System Evaluation Survey
SSO	Sanitary Sewer Overflow
USEPA	United States Environmental Protection Agency
WWP	Wastewater production is the component of dry weather flow that does not include Base Infiltration (BI)

Executive Summary

In 2013-14, City of Redding operated 27 flow monitors in the sewer collection system for the purpose of evaluating dry and wet weather flows. The City also maintains seven rain gauges which were complemented by the Bureau of Reclamation Rain Gauge at Fire Station. The sewer performance analysis utilized data from 26 monitors. During the monitoring period rain gauges recorded three significant rain storms that created sufficient Rainfall Derived Infiltration and Inflow (RDII) for the meters to quantify extraneous flows. Using those data wet weather performance of each monitored basin was evaluated. The concept behind the effort was to quantify the magnitude of RDII to evaluate the effectiveness of City of Redding's ongoing efforts to reduce RDII, reduce peak flows and save capacity at the treatment plants.

Findings

Metric 1: % rainfall entering the system. RDII rates varied from 0.5% to 35.1%. RDII rates above 10% are considered excessive. There does not appear to be any direct correlation between either basin size or length of pipe in this analysis. Table ES1 shows the results of the analysis.

Metric 2: Gallon Per Day per mile length of pipe per inch of pipe diameter. These values are how the monitor areas ranked on scale of 1-10 relative to each other with higher scores indicating higher RDII. There is no indication of magnitude of difference between each area. Table ES2 shows the results of ranking the areas using this metric.

Metric 3: Gallon Per Day per mile length of pipe per inch of rainfall. The monitor areas are ranked for this metric in the same manner as Metric 2. Table ES3 shows the results of this metric.

Metric 4: Average Gallons Per Day per mile of pipe. Table ES4 shows the results of this analysis.

EPA Criteria: The USEPA Handbook: Facilities Planning, 1982 provides criteria for allowable I&I based on length of pipe in the collection system. Table ES5 provides a summary of how the COR monitor areas perform relative to this critera.

>100,000 feet	2,000 – 3,000 Gallons Per Day per inch diameter per mile of pipe
10,000 to 100,000 feet	3,000 – 6,000
<10,000	6,000 – 10,000

The Code of Federal Regulations (40 CFR Sec. 35.2005(28) and (29) provides criteria based on allowable total storm flow based on population. Maximum average daily storm flow is not to exceed 275 gpcd (gallon per capita day). Table ES6 shows how the COR monitoring areas rate relative to this criteria.

Table ES1 – Metric 1

Monitor	% Rainfall as RDII	Excessive?	Basin Area, ac
O11-52	35.13	Excessive	138
M11-15	30.36	Excessive	62
SE15-1	23.48	Excessive	955
N11-24	21.16	Excessive	126
O11-33	19.96	Excessive	211
L4-47	19.34	Excessive	148
L7-40	11.89	Excessive	65
S13-1	10.15	Excessive	1796
F10-61	5.13		2095
L10-72	5.08		694
O13-14	5.07		2191
M9-4	4.02		453
S6-2	3.84		483
T8-6	3.76		4461
D8-5	3.74		1733
G10-3	3.54		885
G11-5	3.02		420
C10-6	2.18		357
SC14-7	2.10		2146
N4-14	1.83		699
R10-30	1.61		985
P6-3	1.40		447
A9-5	0.47		642
S11-8	0.45		391

Table ES2 – Metric 2

Monitor	GPDIM
O11-52	8.2
M11-15	8.0
SE15-1	7.7
O13-14	6.6
L4-47	6.5
A9-5	6.4
L7-40	6.3
N11-24	6.3
F10-61	6.2
S6-2	5.8
O11-33	5.2
S13-1	5.1
G10-3	4.8
M9-4	4.8
T8-6	4.8
N4-14	3.8
D8-5	3.7
G11-5	3.7
L10-72	3.1
P6-3	2.8
SC14-7	2.4
R10-30	2.3
C10-6	2.1
S11-8	0.4

Table ES3 – Metric 3

Monitor	GPDM-in
SE15-1	9.6
O11-52	9.0
M11-15	8.2
S13-1	8.2
L4-47	7.7
N11-24	7.7
O11-33	6.8
F10-61	6.6
O13-14	5.5
L7-40	4.9
D8-5	4.5
A9-5	4.3
SC14-7	4.2
S6-2	3.9
L10-72	3.8
T8-6	3.5
G11-5	3.1
G10-3	3.0
M9-4	2.5
C10-6	2.3
P6-3	1.7
R10-30	1.7
N4-14	1.4
S11-8	0.6

Table ES4 – Metric 4

Monitor	**GPD per Mile**
SE15-1	395,113
O11-52	120,580
M11-15	97,491
S13-1	72,521
N11-24	68,383
O11-33	49,299
L4-47	41,902
F10-61	41,784
L7-40	33,787
O13-14	29,293
SC14-7	23,453
G11-5	22,545
T8-6	19, 580
D8-5	18,908
L10-72	18,091
S6-2	17,901
G10-3	16,653
M9-4	15,454
C10-6	11,222
A9-5	11,108
P6-3	10,263
N4-14	8,924
R10-30	4,919
S11-8	1,841

Table ES5 – EPA Criteria

Area	Length, ft	Average GPD/In-Mi	Allowable GPD/In-Mi	Excessive?	Factor (1)
SE15-1	23,813	124,931	6,000	Excessive	20.8
S13-1	102,944	22,377	3,000	Excessive	7.5
O11-52	16,651	37,617	6,000	Excessive	6.3
F10-61	106,077	12,974	3,000	Excessive	4.3
N11-24	16,115	21,436	6,000	Excessive	3.6
M11-15	8,101	30,785	10,000	Excessive	3.1
O13-14	157,388	9,184	3,000	Excessive	3.1
O11-33	33,522	15,508	6,000	Excessive	2.6
D8-5	129,006	6,480	3,000	Excessive	2.2
T8-6	359,465	6,161	3,000	Excessive	2.1
L4-47	18,766	8,873	6,000	Excessive	1.5
SC14-7	80,353	7,317	6,000	Excessive	1.2
L7-40	9,669	10,737	10,000	Excessive	1.1
L10-72	80,147	5,615	6,000		
G10-3	77,718	5,225	6,000		
M9-4	65,733	5,014	6,000		
C10-6	28,281	3,450	6,000		
A9-5	10,282	3,103	6,000		
S6-2	24,419	2,253	6,000		
R10-30	119,047	1,365	3,000		
P6-3	25,531	1,170	6,000		
N4-14	58,764	1,151	6,000		
S11-8	38,102	551	6,000		
G11-5	36,666				

(1) Recorded Average GPDIM/Allowable Average GPDIM

Table ES6 – 40 CFR Criteria

Area	Capits	Allowable Average GPD	Recorded Average GPD	Excessive?	Factor (1)
SE15-1	364	100,014	3,364,426	Excessive	33.6
O11-52	350	87,901	933,204	Excessive	6.8
A9-5	66	18,062	75,167	Excessive	4.2
G11-5	2067	568,428	1,606,239	Excessive	2.8
S13-1	3570	981,703	2,652,737	Excessive	2.7
F10-61	2616	719,406	1,192,639	Excessive	1.7
M11-15	182	50,094	79,240	Excessive	1.6
SC14-7	1870	514,159	576,113	Excessive	1.1
O13-14	7843	2,156,825	1,173,451		
T8-6	15518	4,267,313	1,068,972		
R10-30	4885	1,343,375	568,162		
D8-5	6755	1,857,604	527,796		
L10-72	3500	962,498	349,582		
O11-33	3199	879,797	320,328		
G10-3	3522	968,484	314,749		
N11-24	986	271,092	196,645		
L4-47	2959	813,659	148,928		
S6-2	2373	652,551	143,811		
N4-14	6173	1,697,630	99,323		
C10-6	832	228,902	93,326		
P6-3	2533	696,654	49,626		
L7-40	552	151,820	31,208		
M9-4	2883	792,738	30,917		
S11-8	3319	912,754	27,748		

(2) Recorded Average GPD/Allowable Average GPD

Recommendations

Recommendations from the 2013-14 analysis include a range of activities from further investigation to scheduling significant areas for pipe replacement projects. Because this analysis is an annual process recommendations were limited to the highest 30% of the ranked RDII areas. The final recommendations include placement of the monitors for the 2014-15 monitoring season. One area in the top third, O11-33, does not appear to have an obvious cause for the excess RDII other than the collection system is aging VCP pipe. Potential actions include smoke testing to see if there are illicit connections to the system or scheduling the area for programmatic pipe replacement. Tables ES7 and ES8 summarize recommendations for the seven remaining highest RDII areas.

ES7 - Inspection and Lining Recomendations

	Video and Potential Lining					Lining				
Area	Upstream MH	Downstream MH	Length, ft	Diameter, in	Material	Upstream MH	Downstream MH	Length, ft	Diameter, in	Material
SE15-1	SC14-7	SE15-2	5960	48	VCP					
O11-52						L10-8	L10-7	453	8	VCP
						L10-10	L10-7	999	8	VCP
						L10-46	L10-47	347	8	VCP
							Total:	1799		
M11-15						L11-72	L11-13	1300	6	VCP
S13-1	P14-2	R15-1	3130	24	VCP					
	O13-14	R13-1	5783	36-29	VCP					
		Total:	8913							
O13-14	G11-2	H11-4	1098	15	VCP					
	G11-25	H11-42	1076	27	VCP					
	H11-41	K11-51	4919	27-30	VCP					
	K11-45	L11-41	2972	30-33	VCP					
		Total:	10065							
N11-24						M11-18	M11-13	295	8	VCP
						M11-12	M11-8	417	6	VCP
						M11-11	M11-20	272	8	VCP
						N11-13	N11-15	375	10	VCP
						O11-12	O11-13	300	10	VCP
							Total:	1659		
F10-61	A9-1	F10-61	9979	21-27	VCP					

ES8 - Replacement and Smoke Testing Recomendations

	Schedule for Replacement						Schedule for Smoke Testing					
Area	Location	Upstream MH	Downstream MH	Length, ft	Diameter, in	Material	Location	Upstream MH	Downstream MH	Length, ft	Diameter, in	Material
O11-52												
	Alfreda	N10-16	O10-30	2543	6	AC						
	Irwin	M10-15	N10-50	1715	6	VCP						
	Irwin	N10-50	O10-33	915	6	VCP						
			Total:	5173								
M11-15							Cameo Ct.	L11-1	L11-4	1026	6	VCP
							Lindeena Ln	L11-8	L11-5	890	6	VCP
							N Deerfield	L11-9	L11-11	650	6	VCP
							Lori Ln.	L11-21	L11-13	758	6	VCP
									Total:	3324		

Chapter 1 – Background

The City of Redding Wastewater Utility initially contacted the Public Works Engineering Division to perform an evaluation of sewer flow data for the purposes of determining the degree of Rain Dependent Infiltration and Inflow (RDII) in the sanitary sewer collection system. Flow Data from 2008-09 was evaluated as part of the 2012 Wastewater Utility Master Plan and deemed unusable. From 2009-11 the utility purchased 28 new flow monitors, obtained training in their installation and use. In 2012-13 improvement in data collection achieved a level where RDII could be evaluated and reported. The current effort was undertaken to evaluate the 2013-14 monitoring data and make recommendations for reduction in RDII.

1.1 Project Objectives

The main objective of this flow data evaluation was to identify whether the isolated sub-drainage basins (basins) within the City collection system experience excessive relative wet weather infiltration and inflow during rain events. This information is then intended to assist the City in more effectively allocating resources to address the impacts of RDII within the collection system.

There were twenty six (26) primary sanitary sewer drainage basins studied; each identified with the manhole designation where the monitor was installed. Eight rain gauges were in operation during the study period and were used to record rainfall associated with the basins within the City sewer system.

1.2 Project Scope of Work

The scope of work for this study included the following tasks:

- Obtain flow and rain data from the collection system areas;
- Conduct and RDII analysis of the rainfall and flow data;
- Evaluate depth of flow and hydraulic performance at each flow monitoring site as applicable (i.e. identify the presence of backwater);
- Quantify RDII basin performance;
- Make recommendations for RDII reduction efforts;
- Make recommendations for 2014-15 monitoring locations.

1.3 Historic RDII analysis

During calibration of the 1987 Master Sewer Plan hydraulic model it was necessary to reduce the estimated service area I and I contributions to take into account the dampening and time delay effects as the various peak flows make their way through the sewers. In the highest I and I areas, only about half of the existing I and I rate was used for modeling purposes. In addition, the highest I and I areas were estimated to be gradually reduced over time from 20 to 30 percent. This reduction was to reflect the anticipated sewer rehabilitation and replacement effort that

would be completed by the time ultimate development occurs approximately 50 years into the future. The total I and I allowance reduction for the existing service areas in 1987 was estimated at about 3.1 mgd by the time ultimate development occurred.

Prior engineering evaluation of RDII for the City of Redding is limited to an evaluation for alternatives to the West Side Interceptor in the West Side Interceptor Project Development Report , 1999. In this effort the 18 basins in the Clear Creek WWTP collection system were evaluated and a cost benefit analysis and comparison was performed between system wide I&I reduction effort and expansion of the system to convey and treat the projected flow including RDII. The effort concluded that to obtain a 30% reduction in I&I would cost approximately $34 million (in 1999 dollars) and only about $17 million (in present worth 1999 dollars) to convey and treat the excess I&I indefinitely. Therefore the Westside Interceptor construction and expansion of the treatment plant was selected as the preferred alternative.

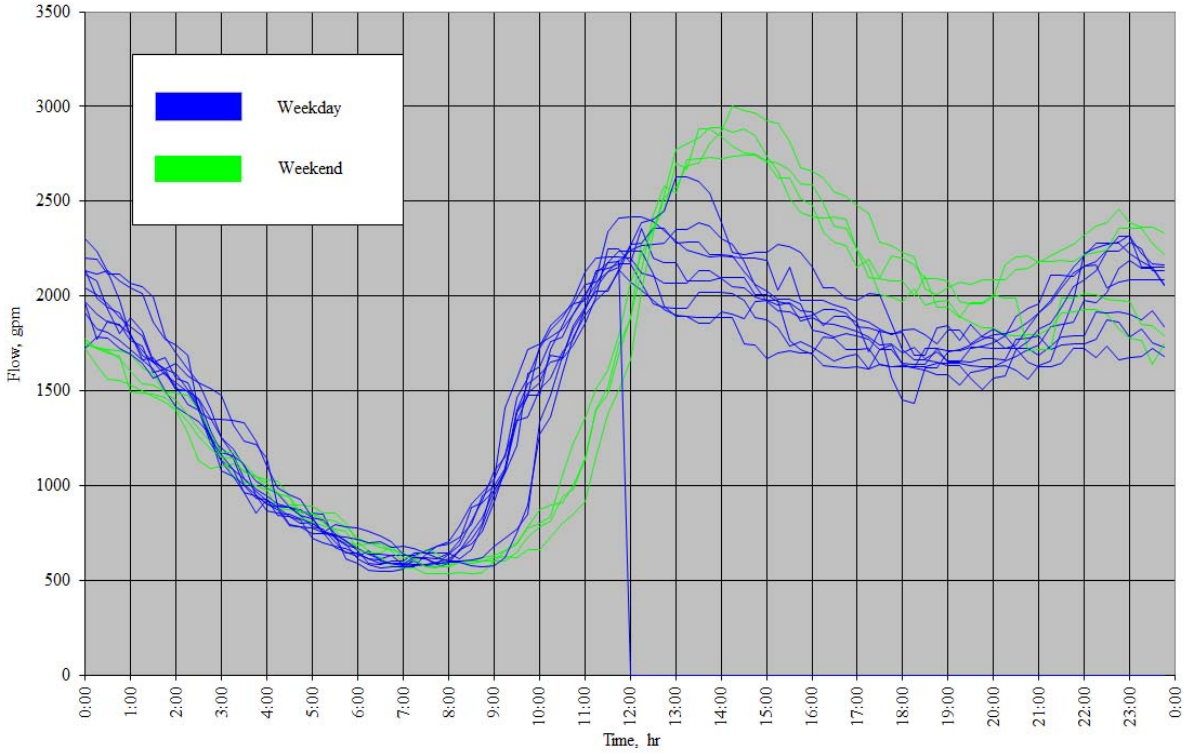
Discussion with other engineering consultants within the last several years, during preparation of the City's Sanitary Sewer Management Plan, disclosed that the City was far enough behind on I & I reduction efforts that there was no opportunity to make significant progress before increased collection system and treatment capacity would be need to avoid SSOs.

Chapter 2 - Dry Weather Hydrograph

Dry weather flow monitoring occurred in the fall of 2013 between October 4th and November 6th. Twenty six monitors were installed at various locations throughout the sewer collection system. Figure 2.1 shows the locations of the monitors and areas being studied. The incremental areas being evaluated ranged in size from 62 acres to 4727 acres. Evaluation of the larger areas was performed to obtain a better understanding of the magnitude of flows rather than evaluating extraneous inflows.

The first step in evaluating extraneous sewer inflow is to obtain a dry weather flow pattern to subtract from the storm flows. This is accomplished by monitoring dry weather conditions, analyzing the data, and preparing a time series of simulated data. Figure 2.2 shows 24-hour dry weather flow traces for the monitor located in manhole SC14-7. It is clear by the difference between weekday and weekend data that an average daily diurnal pattern will not adequately represent the dry weather flows, a weekly pattern will be necessary. Figure 2.3 shows the average weekday and weekend 24-hour patterns used in the simulated DWF time series for SC14-7. Figure 2.4 superimposes the simulated time series over the recorded data to provide a visual evaluation of how well the simulation matches.

Figure 2.2 - SC14-7 DWF



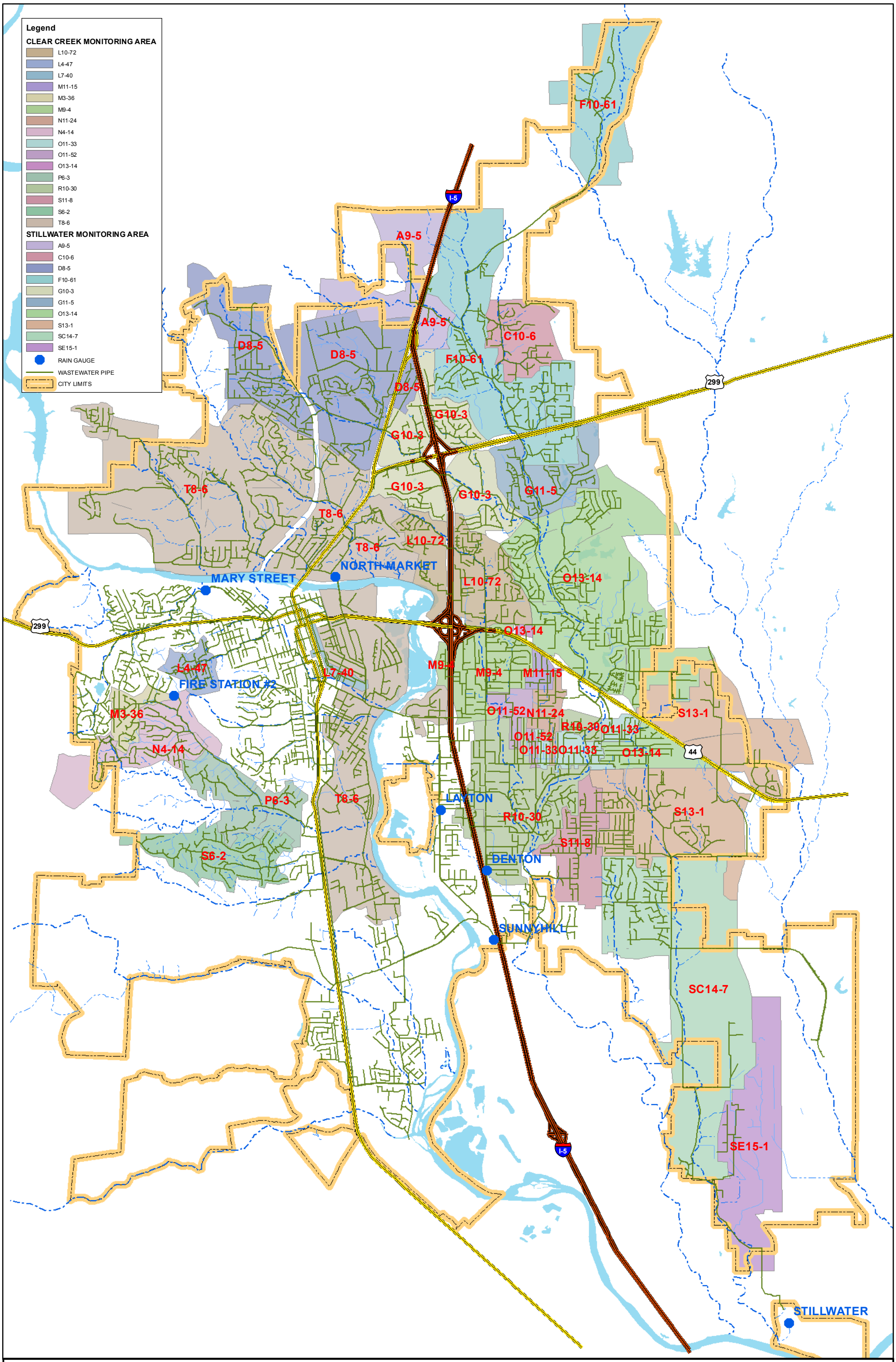


FIGURE 2.1
2013 - 2014 COLLECTION SYSTEM MONITORING

0 0.5 1 2 3 4 Miles

P:\WWater\ESRI\CollectionSystemMonitoring.mxd Aug. 5, 2014

Figure 2.3 - SC14-7 ADWF

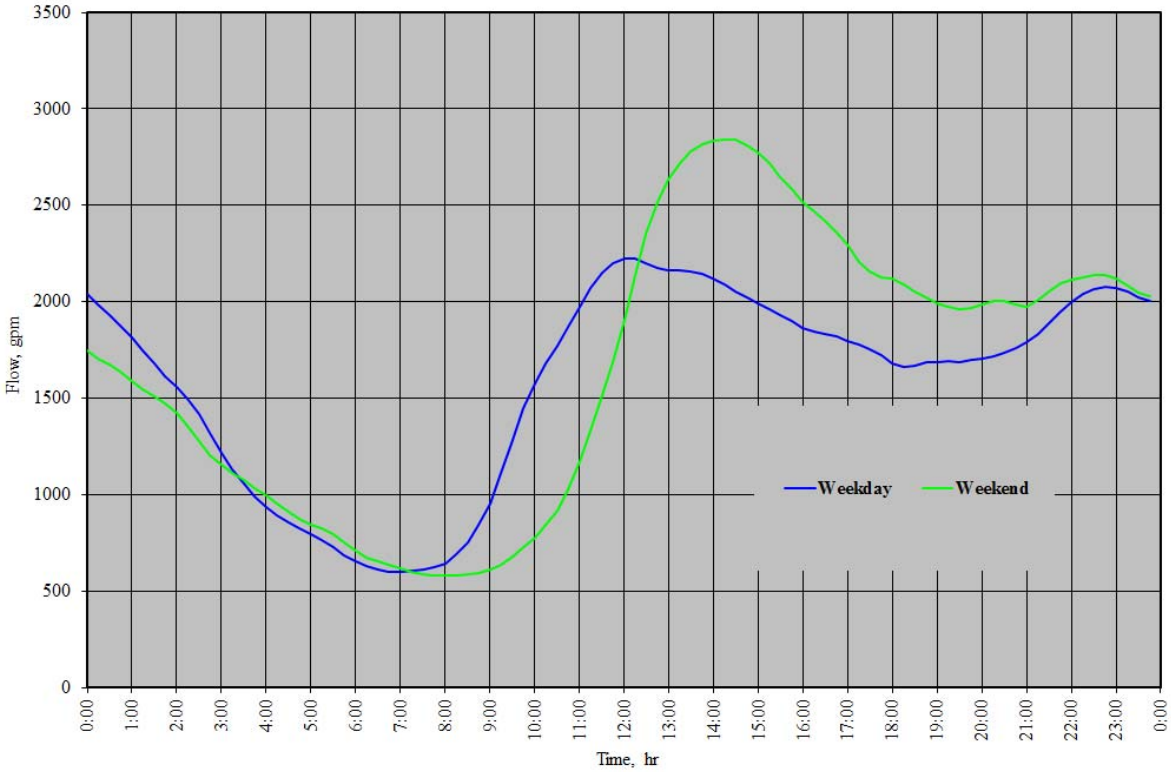
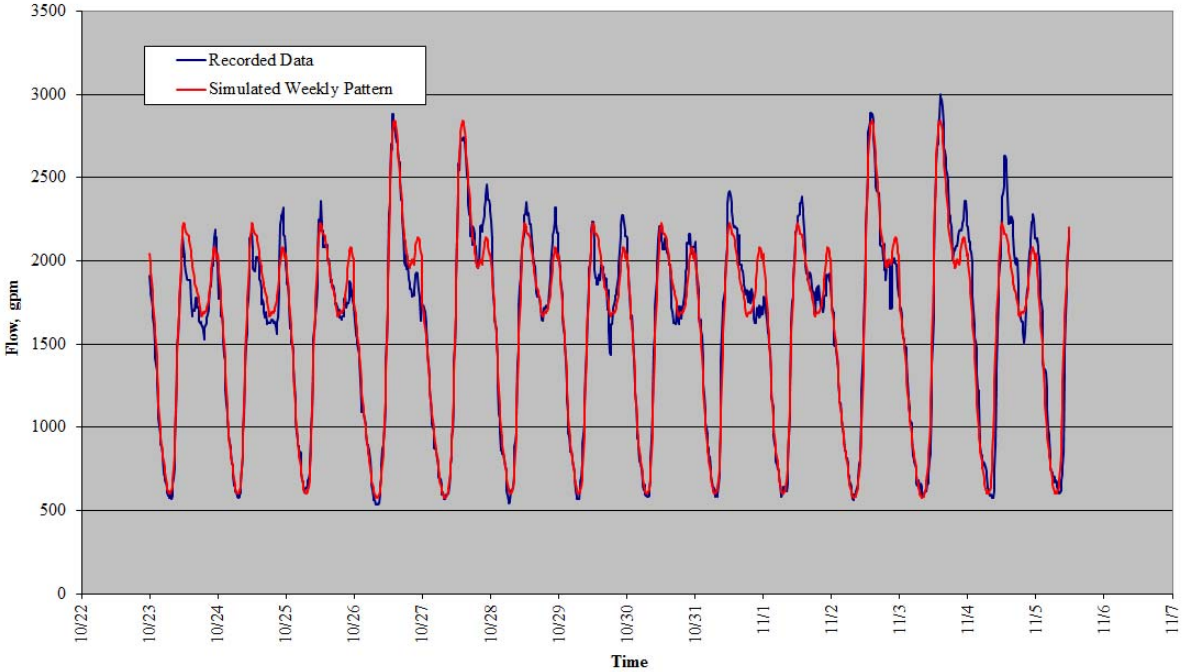


Figure 2.4 - DWF Flow Monitor Record SC14-7



Tabular results of the Dry Weather monitoring effort are show in Table 2.1. Average Gallons Per Day per Household Equivalent (GPD/HE) is 295. The average Diurnal Peaking Factor APH/ADWF is 1.47.

Table 2.1 - 2013-2014 Dry Weather Flow Monitoring Results

Facility	Nearest Street	Manhole	ADWF (MGD)	Area, Ac	HE's	GPD/HE	Average Peak Hour, GPM (1)	APH/ADWF (2)	Peak Hour, gpm	PH/ADWF (3)
Boulder Creek Interceptor	Redwood Blvd	D8-5	0.662	1777	2670	248	608	1.32	657.8	1.43
	Churn Creek Rd	G10-3 (G10-51)	0.897	2671	4062	221	869	1.40	998.8	1.60
Upper Churn Creek Interceptor	Spanish Bay Dr	A9-5	0.019	660	26	732	17	1.31	23.6	1.79
	Hollow Lane	C10-6	0.054	1020	329	164	61	1.64	71.7	1.91
	Collyer Dr	F10-61	0.378	3124	1389	272	392	1.49	508.2	1.94
	Fountain Cir	G11-5	0.713	3553	2206	323	698	1.41	777.6	1.57
Canby Bypass	Mistletoe ln	L10-72	0.395	710	1384	285	407	1.48	475.6	1.73
	Middleton Ln	O11-52	0.712	848	1510	472	721	1.46	859.5	1.74
Area 35 (Deerfield)	Deerfield	M11-15	0.056	62	72	778	61	1.57	72.0	1.85
	Bunker	N11-24	0.105	188	462	227	110	1.51	132.0	1.81
	Shadowbrook Apts	O11-33	0.201	389	1726	116	206	1.48	244.7	1.75
Trinity Street Area	Lincoln Alley	L7-40	0.051	65	218	234	50	1.42	67.2	1.90
San Francisco Area	Almond Ave	L4-47	0.152	146	1169	130	138	1.31	150.7	1.43
	Willis St	Not Installed								
Hilltop Area	Cypress	M9-4	1.224	480	1139	1074	1143	1.34	1208.4	1.42
Starview Estates	Ent Park	S11-8	0.201	371	1312	153	232	1.66	275.1	1.97
Lower Churn Creek Interceptor	Alma Ave	R10-30	1.218	1381	3243	376	1203	1.42	1340.2	1.58
Clover Creek Interceptor	Hartnell	O13-14	1.703	8281	9368	182	1711	1.45	2022.8	1.71
	Freeman	S13-1	1.779	10124	10779	165	1961	1.59	2438.2	1.97
	Lyal Ln	Y13-1	0.986	11491	11481	86	1069	1.56	1394.0	2.04
	Meadow View	SC14-7	2.302	12058	11518	200	2483	1.55	2966.2	1.86
	Hurst	SE15-1	3.513	12334	11662	301	3424	1.40	3780.7	1.55
Canyon Creek	Placer	M3-36	0.195	145	754	258	170	1.26	188.7	1.40
	Teton	N4-14	0.168	684	2440	69	190	1.63	211.4	1.81
	Buenaventura	P6-3	0.293	1106	3441	85	358	1.76	397.7	1.95
Oregon Gulch	Puma Trail	S6-2	0.186	431	938	198	203	1.57	238.9	1.85
Shasta General	Breslauer	T8-6	2.389	5272	7491	319	2246	1.35	2442.9	1.47

(1) Average Peak Hour is the average of the highest hour for each 24-hour period
(2) Average Peak Hour divided by the Average Dry Weather Flow (ADWF)
(3) Absolute Peak Hour divided by the ADWF

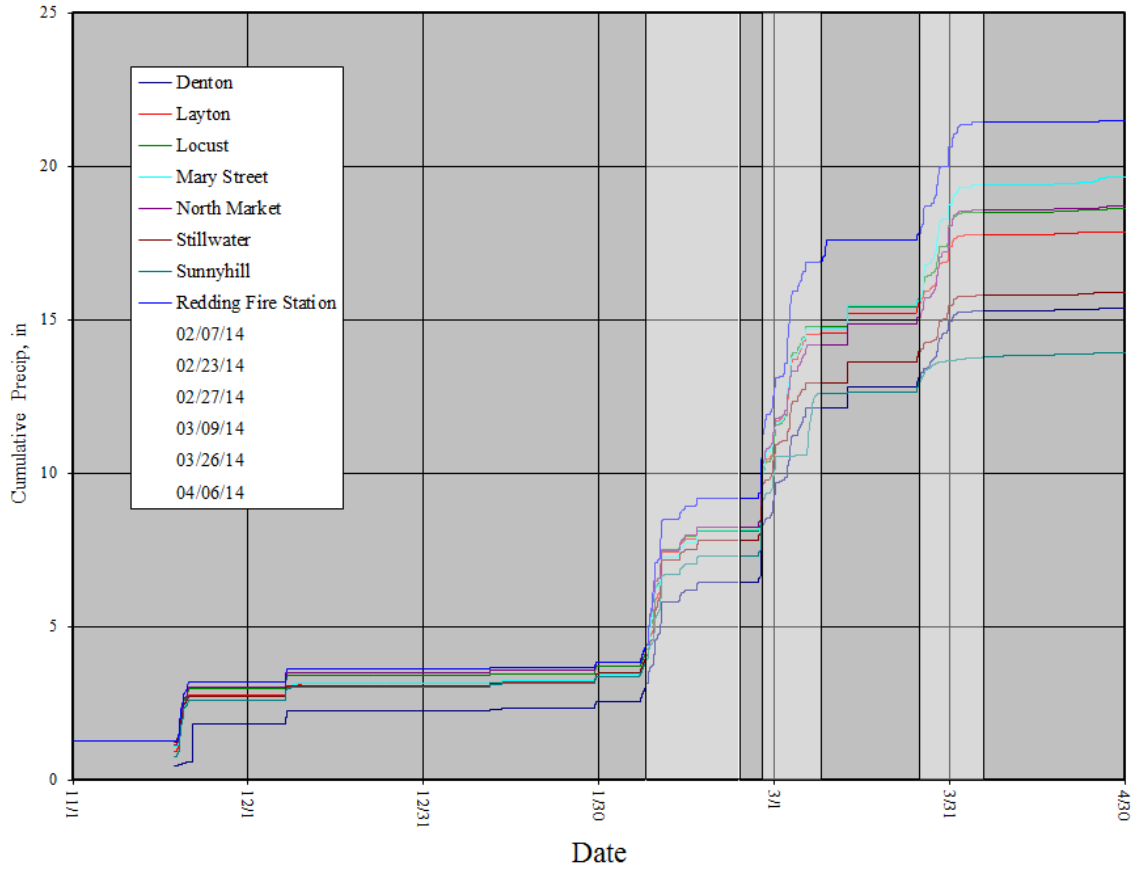
Of the 26 monitors installed two failed to yield usable data. The data record from M3-36 was too noisy to develop a diurnal or weekly pattern from the dry weather flows. Without that time series evaluation of RDII is not possible. The monitor on Lyal Ln at Y13-1 stopped recording consistently in January, prior to any of the three significant storms occurring that winter.

Chapter 3 – Rainfall and Storm Parameters

3.1 City of Redding Precipitation

City of Redding evaluated eight rain gauge recordings to determine storm periods for the winter 2013-14 wet weather monitoring season. Figure 3.1 is a graph of the cumulative rainfall from all eight gauges. Areas shaded light gray were the periods evaluated for RDII. It is significant to note that the total annual rainfall during this particular winter season is extremely low relative to the historic record. Average annual rainfall in the Redding area is about 35 inches and this collection of gauges ranged from approximately 14 to 22 inches for the 2013-14 winter.

Figure 3.1 - 2013-14 Rainfall Records



3.2 Storm Parameters and Significance

A *Significant Storm* is defined as one where the depth of precipitation exceeds 0.50 inches of rain in 20 hours without a dry pause of more than 300 minutes (five hours). All significant storms were used in the RDII analysis. None of the storms with less rain were used.

An *Extreme Storm* is a storm that has a 24-hour rain depth equaled to or exceeding a 10-year return interval. The concept is to be able to size or rehabilitate wastewater facilities in the planning area to be able to contain both dry weather and wet weather flows up to and including an extreme storm, but not necessarily for large storms.

A *Storm Duration* is the length of a significant rain event measured in minutes.

An *Event Duration* is the duration of the RDII event measured in minutes herein. RDII events are the periods of elevated flows created by storm events that often extend for two or more days after the rain event. In Figure 3.1 the first storm area in light grey shading is an Event Duration.

Many agencies including the National Oceanic and Atmospheric Administration (NOAA) classify rainstorms by their *Average Return Intervals* or *Frequency* measured in months or years. NOAA has been collecting such data for over a century. A 2-year storm is a little more than a gentle spring rain, occurring on the average once every two months or about six times per year. A 5-year storm is a much more intense storm, occurring only once in every five years on average. NOAA has amassed a large, national database from which they generate rainfall statistics. More specifically, NOAA generates separate *Depth-Duration-Frequency* (DDF) statistics for each part of the country. This resource can be accessed to evaluate rainfall for the City of Redding for the 2013-14 monitoring effort. Table 3.1 contains the data from NOAA.

Table 3.1 – NOAA DDF data for City of Redding Area, inches precipitation

		Return Interval, yr									
		1	2	5	10	25	50	100	200	500	1000
Duration, min	5	0.201	0.241	0.294	0.339	0.401	0.45	0.501	0.554	0.629	0.688
	10	0.287	0.345	0.422	0.486	0.575	0.645	0.718	0.795	0.901	0.986
	15	0.348	0.417	0.51	0.588	0.695	0.78	0.868	0.961	1.09	1.19
	30	0.462	0.555	0.679	0.782	0.925	1.04	1.16	1.28	1.45	1.59
	60	0.651	0.781	0.955	1.1	1.3	1.46	1.63	1.8	2.04	2.23
	120	0.927	1.1	1.33	1.52	1.79	2	2.22	2.45	2.77	3.02
	180	1.12	1.32	1.6	1.82	2.14	2.38	2.64	2.91	3.28	3.57
	360	1.55	1.84	2.23	2.54	2.98	3.31	3.65	4.01	4.5	4.88
	720	2.08	2.55	3.16	3.64	4.28	4.76	5.24	5.73	6.37	6.86
	1440	2.76	3.52	4.47	5.21	6.17	6.87	7.56	8.24	9.12	9.77
	2880	3.64	4.65	5.91	6.89	8.16	9.09	10	10.9	12.1	12.9

Plotting this data results in a series of lines that can be used for comparison to determine return interval of recent storms. Figure 3.2 is the above data plotted and includes the three storm events

from winter 2013-14 for comparison. Data used for the three storms in 2013-14 was obtained by finding the highest precipitation for each duration listed for each of the storm event periods.

Figure 3.2 - 2013-14 Winter Storm DDF Comparison

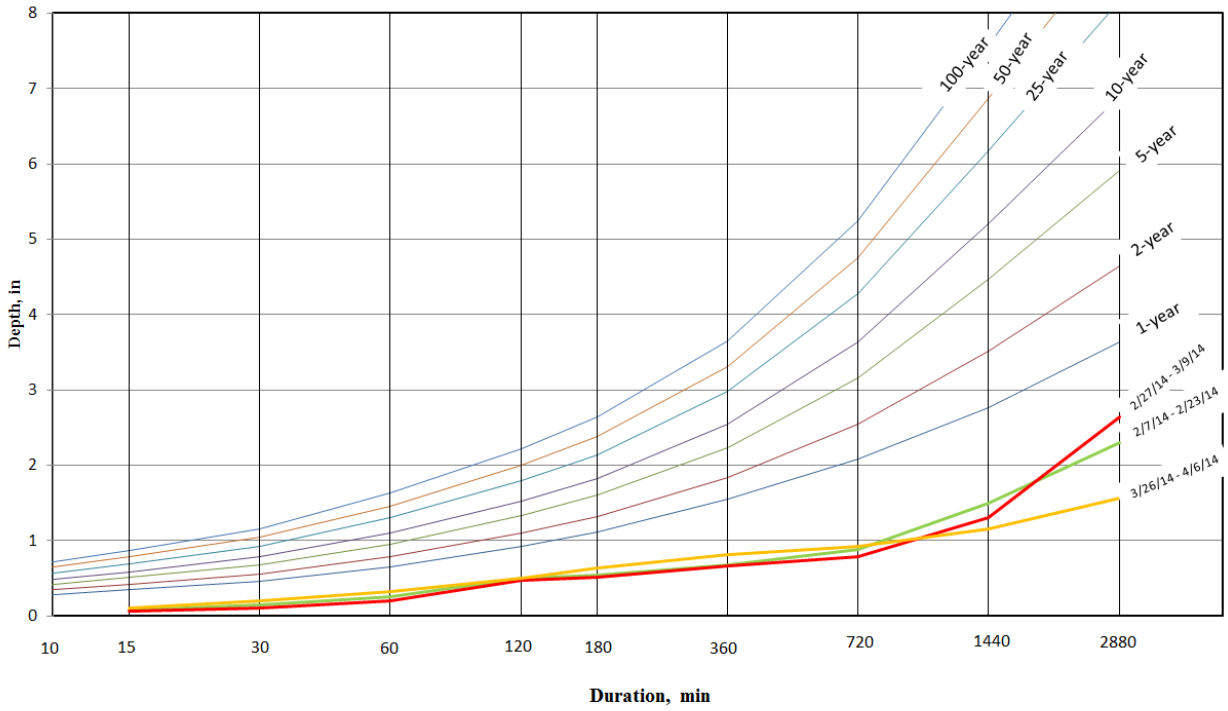


Figure 3.2 reveals that none of the 2013-14 storms reached a magnitude consistent with more than a mild semi-annual event. Because the design criteria for sewers in the City of Redding is a 10-year event the ability to evaluate the absolute magnitude of RDII from these storms is limited. They are however usable for comparative analysis to reveal which areas have higher rates of RDII.

Chapter 4 - Wet Weather Hydrograph

4.1 Wet Weather Components

Infiltration: Water other than waste water that enters a sewerage system (including sewer service connections) through the ground, trough defective pipes, pipe joints, connections or manholes. Infiltration does not include, and is distinguished from inflow.

Inflow: Water other than waste water that enters a sewerage system (including sewer service connections) from sources such as roof leaders, cellar drains, yard drains, area drains, foundation drains, drains from springs and swampy areas, manhole covers, cross connections between storm sewers and sanitary sewers, catch basins, cooling towers, storm waters, surface running street wash waters, or drainage. Inflow does not include, and is distinguished from, infiltration.

RDII: Rainfall Dependent Inflow and Infiltration is that portion of I&I directly influenced by the intensity and duration of a storm event. It consists of storm water inflow and rainfall-dependent infiltration. The term includes infiltration and inflow together because they can't be distinguished on the basis of hydrographs alone. RDII includes those amounts of infiltration and inflow that were generated by rain as opposed to other sources like snowmelt, high river stagers, high tides and groundwater. It takes more field work beyond flow monitoring to distinguish which portion of the wet weather peak flows may have come from direct inflow sources as opposed to those that came from rapid infiltration sources.

Excessive Infiltration/Inflow: The quantities of infiltration and inflow which can be economically eliminated from a sewerage system by rehabilitation, as determined in a cost-effectiveness analysis that compares the costs for correcting the inflow and infiltration conditions to the total costs for transportation and treatment of the excess. (40 CFR, Chapter 1, Subpart E, 35.905 Definitions, 2(c), 2003.)

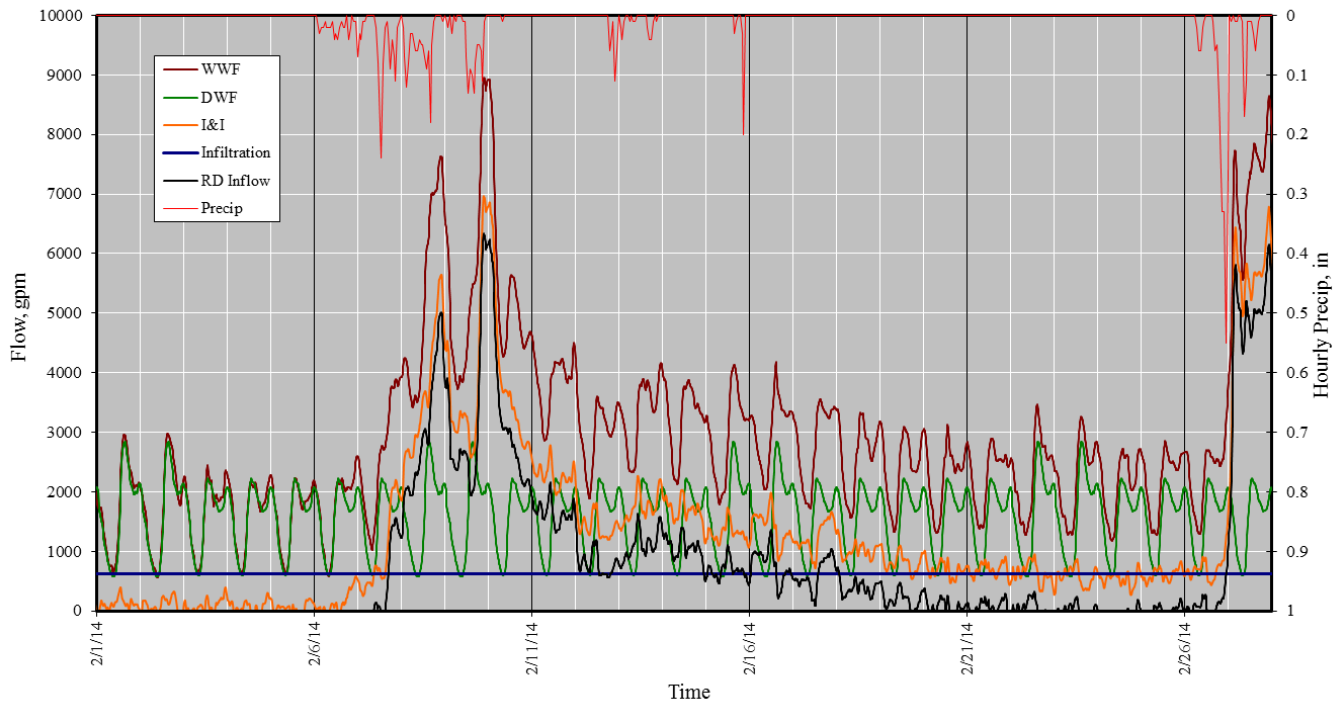
Chronic Operational Problems: Operational problems that result in SSO's during rain events that have average return intervals less than that of an extreme storm. Chronic operational problems may include surcharging, backups, bypasses, and overflows. (40 CFR, Chapter 1, Subpart E, Sec. 35.3005(b)(16) and 35.2120).

Capacity Related SSO: SSOs that occurred because of insufficient sewer capacity during any storm events excluding extreme storm events.

4.2 Wet Weather Hydrograph Decomposition

Decomposition of the wet weather hydrograph separates the flow components to identify wet weather infiltration and RDII. Figure 4.1 shows a wet weather hydrograph of SE14-7.

Figure 4.1 - SC14-7 Wet Weather Hydrograph



In figure 4.1 rainfall is shown in inches per hour in red at the top of the graph with magnitude read on the right side of the figure. The green series shows the simulated weekly dry weather flow time series as described in Chapter 3. The first few days shows that the simulated DWF series still matches the recorded DWF verifying its accuracy. The brown series is the total recorded sewer flow including all components. If we subtract the DWF from the total we have the total I&I which is shown as the orange series. If the difference was all RDII then we would see the orange line drop to zero after a few days. For this monitor this doesn't happen. The difference continuing for an extended period of time indicates there is wet season infiltration. It's not directly storm related but probably the result of leaky collection system under or adjacent to a creek. In this case Clover Creek. Figure 4.1 is the February Wet Weather Hydrograph for this monitor. The difference continues through the end of the monitoring period in April. The flat blue series at across the bottom of the graph at approximately 650 gpm is the approximation of this infiltration amount. If we subtract this infiltration amount from the total I&I we get the RDII which is shown in black and it returns to zero within a few days following the end of

rainfall. The black time series is the series we integrate to determine the volume and flow rate for RDII.

Once we have performed this analysis for each monitor we need to determine length of sewer pipe in each monitoring area and sewer footprint in each area. The sewer footprint is the number of miles of pipe per inch of pipe frequently expressed as inch-miles. Once we have gathered all the data we can then start to evaluate the areas relative to each other and hopefully against some standard performance metric.

4.3 RDII Evaluation Methods and Metrics

Since the start of the EPA's Construction Grants program in the 1970's different I/I or RDII metrics have been applied to collection systems to help determine whether flows in the sewers were "excessive". Early evaluations were supposed to be based on pure cost-effectiveness where the costs for correcting the infiltration /inflow conditions were compared to the total costs for transportation and treatment of the infiltration/inflow. Since few engineers can predict the effectiveness of rehabilitation, cost-effectiveness analysis were impossible for most communities, so EPA began developing simple RDII surrogates, known as metrics. Table 4.2 reviews the different EPA metrics.

Table 4.2 – Historic Excessive I/I Criteria from EPA

Criteria Source	Criteria for Non-excessive Infiltration Determination	
USEPA Program Requirements Memorandum (PRM 79-10, 1978)	Established 1,500 gal/day/inch-mile (gpdim) as nonexcessive leakage allowance, perform a cost-effectiveness analysis to determine if the leakage is possibly excessive and qualifies for investigation.	
Draft Program Requirements Memorandum (PRM 80, 1980)	Proposed 3,000 gpdim as nonexcessive allowance, maximum of 30% infiltration removal for use in cost-effectiveness analysis (CEA).	
USEPA Handbook: Procedures for Investigating Infiltration/Inflow, EPA 68-01-4913, 1981.	**Nonexcessive Allowance Ranges**	
	Nonexcessive Rate	**Length of Sewer**
	2,000 – 3,000 gpdim	>100,000 lf
	3,000 – 5,000 gpdim	50,000 – 100,000 lf
	5,000 – 8,000 gpdim	1,000 – 50,000 lf
EPA Handbook: Facilities Planning, 1982	**Nonexcessive Rate**	**Length of Sewer**
	2,000 – 3,000 gpdim	>100,000 lf
	3,000 – 6,000 gpdim	10,000 – 100,000 lf
	6,000 – 10,000 gpdim	<10,000 lf
USEPA Handbook: Sewer System Infrastructure Analysis and Rehabilitation EPA 625/6-91/030, 1991	**Nonexcessive Infiltration**	
	Preceding year's 7-14 day high groundwater wastewater flow less than or equal 120 gpcd.	
40 CFR Sec. 35.2005(28) and (29)	**Nonexcessive Inflow**	
	Total daily average storm flow less than or equal 275 gpcd	
	No operational problems in collection system and WWTP	

This report used six different metrics to evaluate and compare the different monitored areas. During this process it became clear that there were areas distinctly higher in RDII relative to others and deemed excessive by the EPA metric criteria listed in Table 4.2.

Metric 1: Percent precipitation entering the system. The volume of rainfall falling on a monitored area can be calculated from the depth of rainfall during the storm event period and the total area of that area. Integrate the RDII curve described in Chapter 3 for each monitor for each storm event and divide this by the total respective volume of rainfall to calculate the percent entering the system. This yields a result for each area for each event. The values were averaged for each area and are presented in Table 4.3. This metric can be pretty misleading because some areas are very large relative to the length of collection system pipe meaning that a significant portion of the rainfall would have no opportunity to enter the collection system. None the less some agencies use this as a method of evaluating excessive RDII whereby anything higher than 10% is deemed excessive.

Table 4.3 – Metric 1: Percent rainfall entering

Area	% Rainfall as RDII	Excessive?	Basin Area, ac
O11-52	35.13	Excessive	138
M11-15	30.36	Excessive	62
SE15-1	23.48	Excessive	955
N11-24	21.16	Excessive	126
O11-33	19.96	Excessive	211
L4-47	19.34	Excessive	148
L7-40	11.89	Excessive	65
S13-1	10.15	Excessive	1796
F10-61	5.13		2095
L10-72	5.08		694
O13-14	5.07		2191
M9-4	4.02		453
S6-2	3.84		483
T8-6	3.76		4461
D8-5	3.74		1733
G10-3	3.54		885
G11-5	3.02		420
C10-6	2.18		357
SC14-7	2.10		2146
N4-14	1.83		699
R10-30	1.61		985
P6-3	1.40		447
A9-5	0.47		642
S11-8	0.45		391

Metric 2: Gallons Per Day per Inch diameter per Mile length of pipe. This metric is identified in the EPA criteria for excessiveness and was developed in this report as a tool to compare relative differences between the different areas. Once the value was calculated for each area for each event they were ranked within each event creating three ranking scores for each area. These scores were summed for each area and the new list scaled to 1-10 with higher numbers being the higher RDII area. Table 4.4 presents the results of this metric.

Table 4.4 – Metric 2

Area	GPDIM
O11-52	8.2
M11-15	8.0
SE15-1	7.7
O13-14	6.6
L4-47	6.5
A9-5	6.4
L7-40	6.3
N11-24	6.3
F10-61	6.2
S6-2	5.8
O11-33	5.2
S13-1	5.1
G10-3	4.8
M9-4	4.8
T8-6	4.8
N4-14	3.8
D8-5	3.7
G11-5	3.7
L10-72	3.1
P6-3	2.8
SC14-7	2.4
R10-30	2.3
C10-6	2.1
S11-8	0.4

Table 4.5 – Metric 3

Area	GPDM-in
SE15-1	9.6
O11-52	9.0
M11-15	8.2
S13-1	8.2
L4-47	7.7
N11-24	7.7
O11-33	6.8
F10-61	6.6
O13-14	5.5
L7-40	4.9
D8-5	4.5
A9-5	4.3
SC14-7	4.2
S6-2	3.9
L10-72	3.8
T8-6	3.5
G11-5	3.1
G10-3	3.0
M9-4	2.5
C10-6	2.3
P6-3	1.7
R10-30	1.7
N4-14	1.4
S11-8	0.6

Metric 3: Metric 3 uses inch of rainfall instead of inch-mile of pipe so the divisor is total rainfall during the storm event. This method has a significant amount of uncertainty if the storm events are not regional or have a significant cloudburst component that may not be picked up by rain gauges. Results from this analysis were ranked and scored in the same manner as those in Metric 2. Results of Metric 3 are presented in Table 4.5.

Metric 4: In this analysis the Gallons Per Day per mile of pipe was evaluated. This value is something worth presenting so the results were not ranked against each other but averaged for each area across the three storm events and presented in Table 4.6.

Table 4.6 – Metric 4

Area	GPD per Mile
SE15-1	395,113
O11-52	120,580
M11-15	97,491
S13-1	72,521
N11-24	68,383
O11-33	49,299
L4-47	41,902
F10-61	41,784
L7-40	33,787
O13-14	29,293
SC14-7	23,453
G11-5	22,545
T8-6	19, 580
D8-5	18,908
L10-72	18,091
S6-2	17,901
G10-3	16,653
M9-4	15,454
C10-6	11,222
A9-5	11,108
P6-3	10,263
N4-14	8,924
R10-30	4,919
S11-8	1,841

Metric 5: EPA Handbook: Facilities Planning, 1982 Criteria. This metric utilizes a crude step function to evaluate the allowable amount of Gallons per Day per Inch Mile of pipe as shown in Table 4.2. Results of this evaluation are shown in Table 4.7. This table includes a factor indication the ratio by which the recorded RDII exceeds the allowable. Areas were ranked by that factor followed by the value of GPDIM for areas that were not deemed excessive.

Metric 6: 40 CFR Sec. 35.2005(28) and (29). This metric is also somewhat crude because an area without much population may have significant length of interceptor. Results are presented in Table 4.8.

Table 4.7 – Metric 5: EPA Criteria

Area	Length, ft	Average GPD/In-Mi	Allowable GPD/In-Mi	Excessive?	Factor
SE15-1	23,813	124,931	6,000	Excessive	20.8
S13-1	102,944	22,377	3,000	Excessive	7.5
O11-52	16,651	37,617	6,000	Excessive	6.3
F10-61	106,077	12,974	3,000	Excessive	4.3
N11-24	16,115	21,436	6,000	Excessive	3.6
M11-15	8,101	30,785	10,000	Excessive	3.1
O13-14	157,388	9,184	3,000	Excessive	3.1
O11-33	33,522	15,508	6,000	Excessive	2.6
D8-5	129,006	6,480	3,000	Excessive	2.2
T8-6	359,465	6,161	3,000	Excessive	2.1
L4-47	18,766	8,873	6,000	Excessive	1.5
SC14-7	80,353	7,317	6,000	Excessive	1.2
L7-40	9,669	10,737	10,000	Excessive	1.1
L10-72	80,147	5,615	6,000		
G10-3	77,718	5,225	6,000		
M9-4	65,733	5,014	6,000		
C10-6	28,281	3,450	6,000		
A9-5	10,282	3,103	6,000		
S6-2	24,419	2,253	6,000		
R10-30	119,047	1,365	3,000		
P6-3	25,531	1,170	6,000		
N4-14	58,764	1,151	6,000		
S11-8	38,102	551	6,000		
G11-5	36,666				

Table 4.8 – Metric 6: 40 CFR Criteria

Area	Capits	Allowable Average GPD	Recorded Average GPD	Excessive?	Factor
SE15-1	364	100,014	3,364,426	Excessive	33.6
O11-52	320	87,901	933,204	Excessive	6.8
A9-5	66	18,062	75,167	Excessive	4.2
G11-5	2067	568,428	1,606,239	Excessive	2.8
S13-1	3570	981,703	2,652,737	Excessive	2.7
F10-61	2616	719,406	1,192,639	Excessive	1.7
M11-15	182	50,094	79,240	Excessive	1.6
SC14-7	1870	514,159	576,113	Excessive	1.1
O13-14	7843	2,156,825	1,173,451		
T8-6	15518	4,267,313	1,068,972		
R10-30	4885	1,343,375	568,162		
D8-5	6755	1,857,604	527,796		
L10-72	3500	962,498	349,582		
O11-33	3199	879,797	320,328		
G10-3	3522	968,484	314,749		
N11-24	986	271,092	196,645		
L4-47	2959	813,659	148,928		
S6-2	2373	652,551	143,811		
N4-14	6173	1,697,630	99,323		
C10-6	832	228,902	93,326		
P6-3	2533	696,654	49,626		
L7-40	552	151,820	31,208		
M9-4	2883	792,738	30,917		
S11-8	3319	912,754	27,748		

If all six metrics are assigned the same value ranking and scoring each area results in the following order of areas from highest RDII to lowest.

Rank	Area	Rank	Area
1	SE15-1	13	S6-2
2	O11-52	14	D8-5
3	M11-15	15	L10-72
4	S13-1	16	A9-5
5	O11-14	17	G11-5
6	N11-24	18	G10-3
7	O11-33	19	M9-4
8	F10-61	20	R10-30
9	L4-47	21	N4-14
10	T8-6	22	P6-3
11	L7-40	23	C10-6
12	SC14-7	24	S11-8

4.4 Conclusions and Recommendations

The last ranking is sufficient to initiate detailed investigation and make recommendations on an individual area basis for the top 30% starting at the top of the list. Table 4.9 and 4.10 summarize the recommendations including manhole numbers lengths and diameters of the affected pipes. Table 4.11 provides recommendations for placement of monitors for the 2014-15 monitoring season.

SE15-1

This area is the lower portion of the Clover Creek Interceptor. During the last Wastewater Utility Master Plan in discussion with Frank Sawyer, a long time development engineer, city staff was reminded that construction of the Clover Creek Interceptor was very problematic even resulting in litigation with the contractor over construction quality issues. He suspected that we would be getting excessive I&I as a result. Discussion with Stillwater WWTP supervisors also indicated there may be a problem because of the magnitude of difference between flows at Churn Creek Lift Station and the Treatment Plant was not justified given the length of pipe and number of services.

Wet weather infiltration (WWI) alone indicates there is a problem. At SC14-7 the WWI is approximately 650 gpm and by the time the interceptor reaches SE15-1 it doubles to approximately 1200 gpm. That’s almost 0.8 MGD every day during the wet season. Total RDII for storm event periods is an average of 3.4 MGD (Table 4.8) over the 37 days analyzed in the 2013-14 season.

It is recommended that the City proceed immediately with an effort to send a camera through the interceptor in attempt to identify specific areas to reline or repair. If a video recording during dry weather does not reveal obvious areas to address then repeat the recording effort at the first wet weather opportunity and follow up with lining or repairs in 2015. Further monitoring of this specific area should not be necessary in winter 2014-15. Follow up monitoring is recommended following rehabilitation effort to document efficacy. Figure 4.2 shows the location of the recommended investigation.

O11-52

Area O11-52 is a mix of older residential, multiple family and recently constructed commercial land use. Results from this area are complicated due to a diversion manhole at the upstream end. Mapping of the area does not include areas upstream of this diversion manhole. However, it is unknown how much or if any flow from the upstream area drains into O11-52. If this was occurring, which is likely, the RDII value would be artificially high. The configuration of this manhole is currently under investigation and it may be reasonable to install monitors on both downstream branches in 2014-15. Meanwhile, much of the collection system is VCP in or near or crossing creeks or ditches. It is recommended that a lining project be instigated to rehabilitate or seal all pipes in, adjacent to or under these ditches and creeks. Figure 4.3 shows the location of area O11-52.

M11-15

This area is an older residential area that has been problematic from and RDII perspective for some time. In the early 2000s a rehabilitation/sealing project was performed which failed to make any measurable improvement. The pipes downstream have been increased in size to manage the issue including a parallel bypass pipe. The area contributes an average of 79,240 gallons per day RDII during storm events which is relatively low compared to most other areas, only has 8,101 feet of pipe, covers only 62 acres and has a population of only 182 people. It is suspected that because the area is relatively flat and lacking adequate drainage facilities residents may be utilizing the sanitary sewer system to dispose of excess storm water. There is one stretch of VCP pipe along the north side of Oakdale Lane located directly under a drainage ditch. This will be included in the plan for pipe lining. It is recommended that this area be targeted for smoke testing and continued monitoring. Figure 4.4 shows the location of area M11-15.

S13-1

This area is a significant size area including upper Clover Creek Interceptor, the Sports Complex, industrial areas north of HWY 44 and residential area east of Clover Creek Preserve and residential area west of Shasta View. One large diameter VCP pipe runs under the wetland

complex in Clover Creek Preserve. Two manholes upstream of S13-1 three sewer pipes drain into one manhole (R13-1). It is recommended that the three branches be monitored in 2014-15 to try and determine further action. It is further recommended that video recording of the pipe under Clover Creek Preserve be performed during wet weather flow to investigate potential excess RDII in that location. It is also known that during construction of the Sports Complex there were problems with excess sewer contributions which were assumed to be temporary contractor cross connections between Stormwater problem areas and the sanitary sewer. It is recommended that a monitor be installed for the 2014-15 winter season to investigate the possibility that such issues were not resolved. There are numerous runs of VCP in this area that are adjacent to or crossing under Clover Creek and the west tributary to Stillwater Creek. These are additional areas that could be investigated by video recording for excess RDII. Figure 4.5 shows the location of area S13-1.

O13-14

The O13-14 area includes a significant length of East Side Interceptor upstream of Churn Creek lift Station, a small portion of Clover Creek interceptor, residential areas along Shasta View and Old Alturas and limited industrial areas around Viking Way. The likely source of excess RDII is the East Side Interceptor which is large diameter VCP parallel to and on the bank of Churn Creek. This pipe is another candidate for video recording of wet weather flows and potential lining projects. Figure 4.6 shows the location of area O13-14.

N11-24

The area monitored by N11-24 has been the target of unsuccessful I&I reduction efforts in the past and continues to be high on the list of areas to address. The problems are very similar to those in area M11-15. Recommendations for additional work in this area are to repeat the smoke testing effort on smaller areas using larger volumes of smoke. Also to include several pipes crossing creeks or ditches in the pipe lining effort. Figure 4.7 shows the location of area N11-24.

O11-33

O11-33 is an area of older residential land use, relatively flat terrain and older VCP pipes. There does not appear to be any obvious causes so a couple locations will be included in the pipe lining recommendations and the rest needs to be scheduled for replacement. Figure 4.8 shows the location of area O11-33.

F10-61

Land use in this area is primarily residential and includes the upper Churn Creek Interceptor and Tierra Oaks Lift station. Most of the smaller diameter collector pipes are relatively new construction but there are larger diameter VCP interceptors immediately adjacent to creeks. It is recommended that video recording be performed on these pipes during wet weather flows in winter 2014-15 to attempt to identify specific lengths of pipe for rehabilitation, most likely lining. It is recommended that additional monitoring occur in 2014-15 to try and identify more specifically the source of the I&I. Figure 4.9 shows the location of area F10-61.

Table 4.9 - Inspection and Lining Recomendations

	Video and Potential Lining					Lining				
Area	Upstream MH	Downstream MH	Length, ft	Diameter, in	Material	Upstream MH	Downstream MH	Length, ft	Diameter, in	Material
SE15-1	SC14-7	SE15-2	5960	48	VCP					
O11-52						L10-8	L10-7	453	8	VCP
						L10-10	L10-7	999	8	VCP
						L10-46	L10-47	347	8	VCP
							Total:	1799		
M11-15						L11-72	L11-13	1300	6	VCP
S13-1	P14-2	R15-1	3130	24	VCP					
	O13-14	R13-1	5783	36-29	VCP					
		Total:	8913							
O13-14	G11-2	H11-4	1098	15	VCP					
	G11-25	H11-42	1076	27	VCP					
	H11-41	K11-51	4919	27-30	VCP					
	K11-45	L11-41	2972	30-33	VCP					
		Total:	10065							
N11-24						M11-18	M11-13	295	8	VCP
						M11-12	M11-8	417	6	VCP
						M11-11	M11-20	272	8	VCP
						N11-13	N11-15	375	10	VCP
						O11-12	O11-13	300	10	VCP
							Total:	1659		
F10-61	A9-1	F10-61	9979	21-27	VCP					

Table 4.10 - Replacement and Smoke Testing Recomendations

	Schedule for Replacement						Schedule for Smoke Testing					
Area	Location	Upstream MH	Downstream MH	Length, ft	Diameter, in	Material	Location	Upstream MH	Downstream MH	Length, ft	Diameter, in	Material
O11-52												
	Alfreda	N10-16	O10-30	2543	6	AC						
	Irwin	M10-15	N10-50	1715	6	VCP						
	Irwin	N10-50	O10-33	915	6	VCP						
			Total:	5173								
M11-15							Cameo Ct.	L11-1	L11-4	1026	6	VCP
							Lindeena Ln	L11-8	L11-5	890	6	VCP
							N Deerfield	L11-9	L11-11	650	6	VCP
							Lori Ln.	L11-21	L11-13	758	6	VCP
									Total:	3324		

Table 4.11 2014-15 Sewer Monitoring Plan

No.	Facility	Nearest Street	Manhole	Alternate Manhole
1	Diversion Manhole L10-7	Del Monte St.	M10-35	M10-34
2		Mistletoe School	L10-8	L10-9
3	Area 35 (Deerfield)	Deerfield	M11-15	(1)
4		Bunker	N11-24	(1)
5		Shadowbrook Apts	O11-33	(1)
6	San Francisco Area	Almond Ave	L4-47	(1)
7		Willis	K5-8	K5-108
8	Hilltop Area	Cypress	M9-4	(1)
9	Canby Bypass	Mistletoe ln	L10-72	(1)
10	Clover Creek Interceptor	Insbruck Dr	N14-5	N14-4
11		Hartnell	O13-14	(1)
12		CCP-1	R13-5	R13-6
13		CCP-2	R13-2	R13-3
14		Freeman	S13-1	(1)
15		Meadow View	SC14-7	(1)
16		Hurst	SE15-1	(1)
17	Upper Churn Creek Interceptor	Churn Creek Trail	F10-61	(1)
18		Collyer Dr.	D10-6	D10-7
19		Oasis Center PII	NZ9-1	NZ9-2
20		Wales Dr.	C10-2	C10-1
21	Boulder Creek Interceptor	Redwood Blvd	D8-5	(1)
22		Churn Creek Rd	G10-3	(1)
23	Lake Redding	Delta Street	H6-20	H6-19
24		Harlan Dr.	H4-35	G4-4
25		Lake Redding Dr.	H4-10	H4-11
26		Traveled Way	H6-42	H6-16
27		McConnell Campus	H7-7	H7-9
28	Reserve on the shelf			

(1) Manhole monitored in 2013-14

Figure 4.2 - Location of Area SE15-1

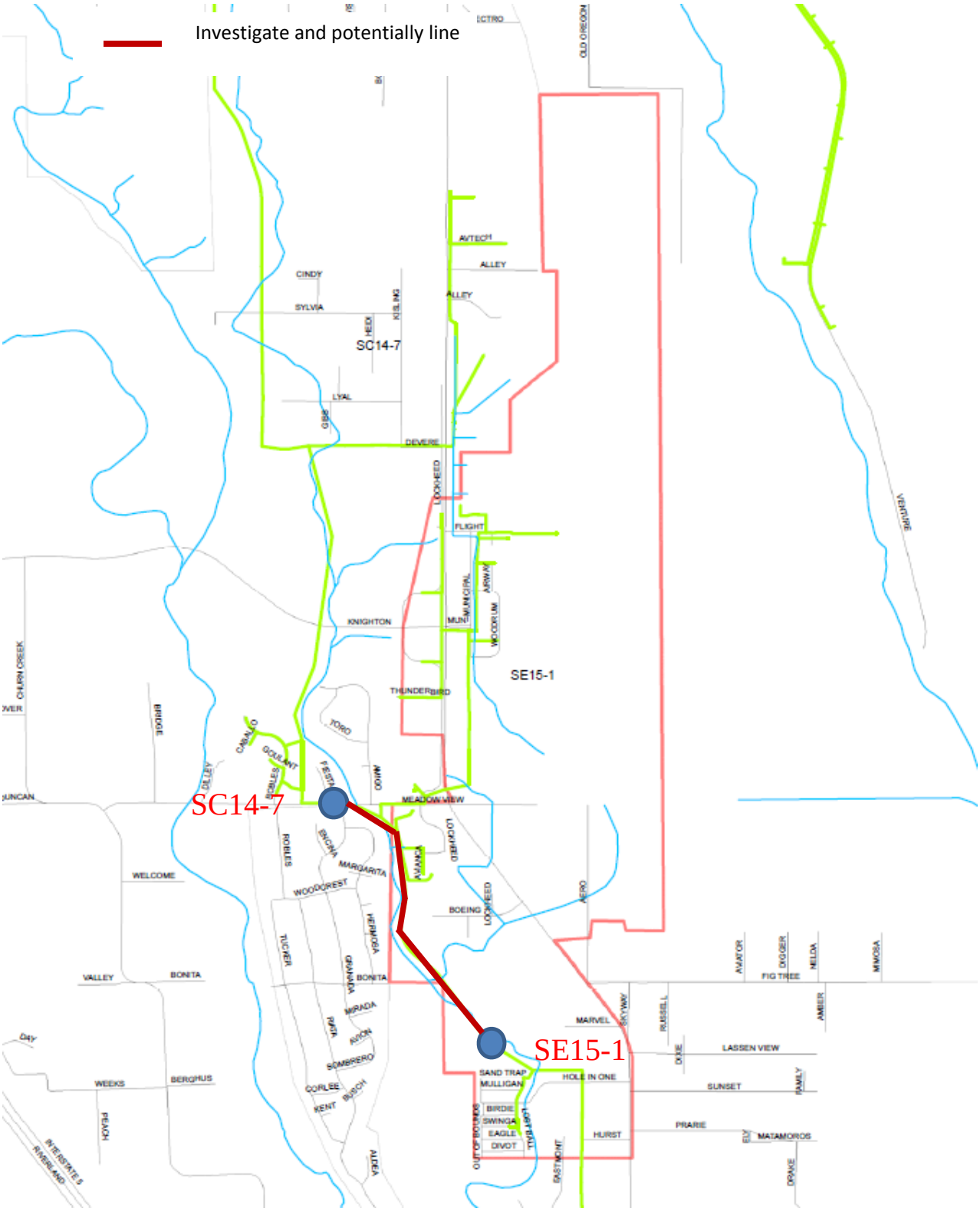


Figure 4.3 - Location of Area O11-52

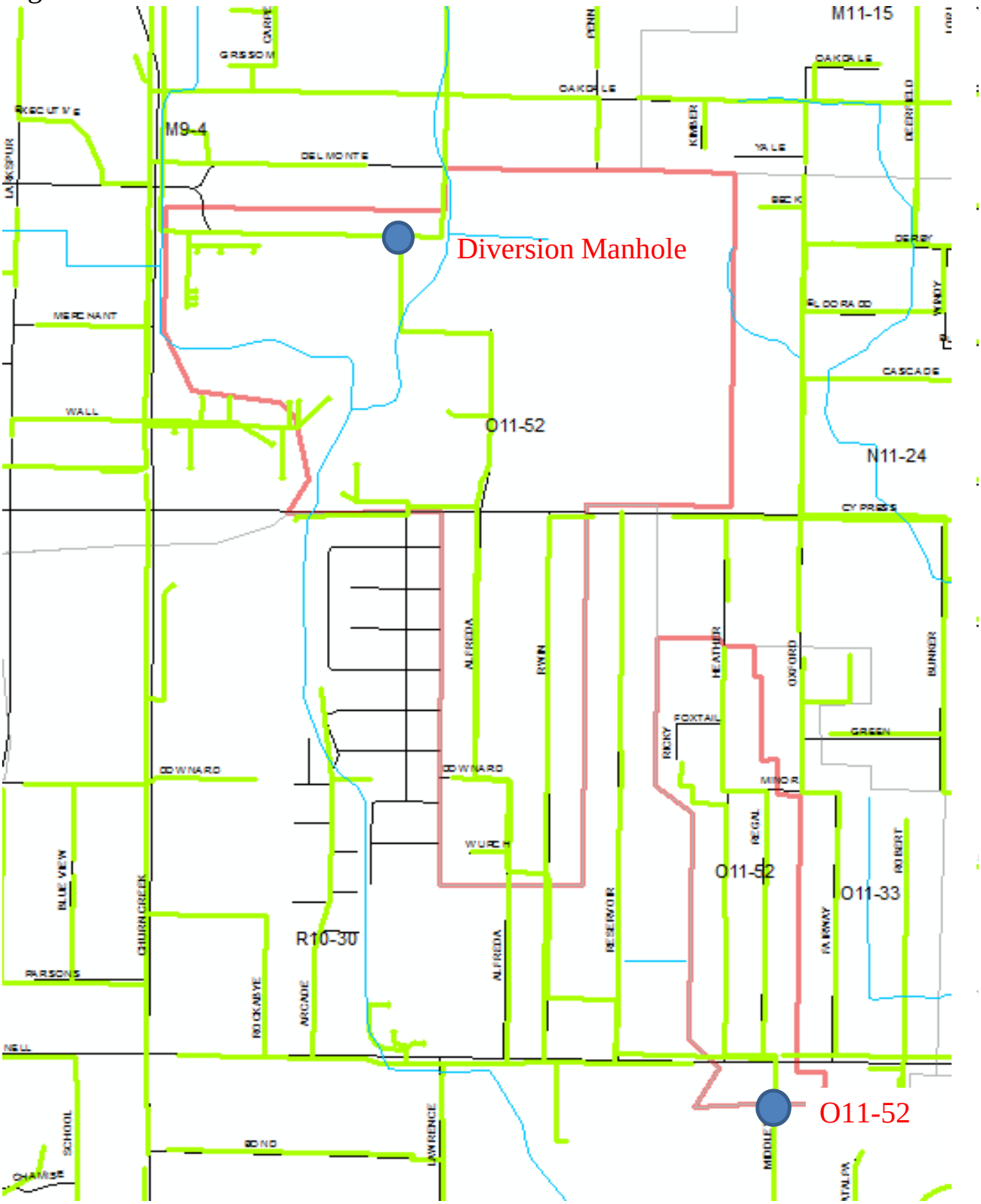


Figure 4.4 - Location of Area M11-15

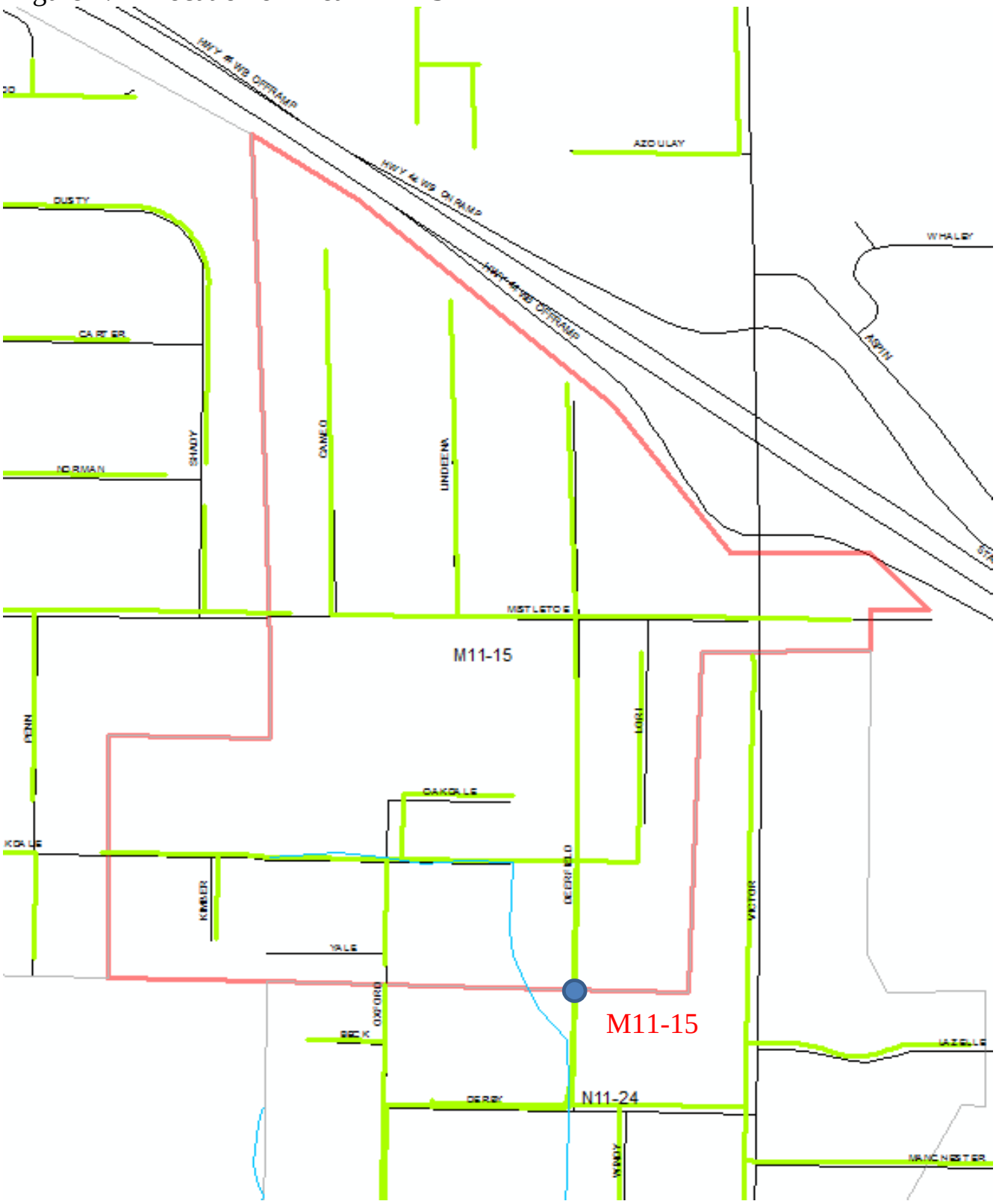


Figure 4.5 - Location of Area S13-1

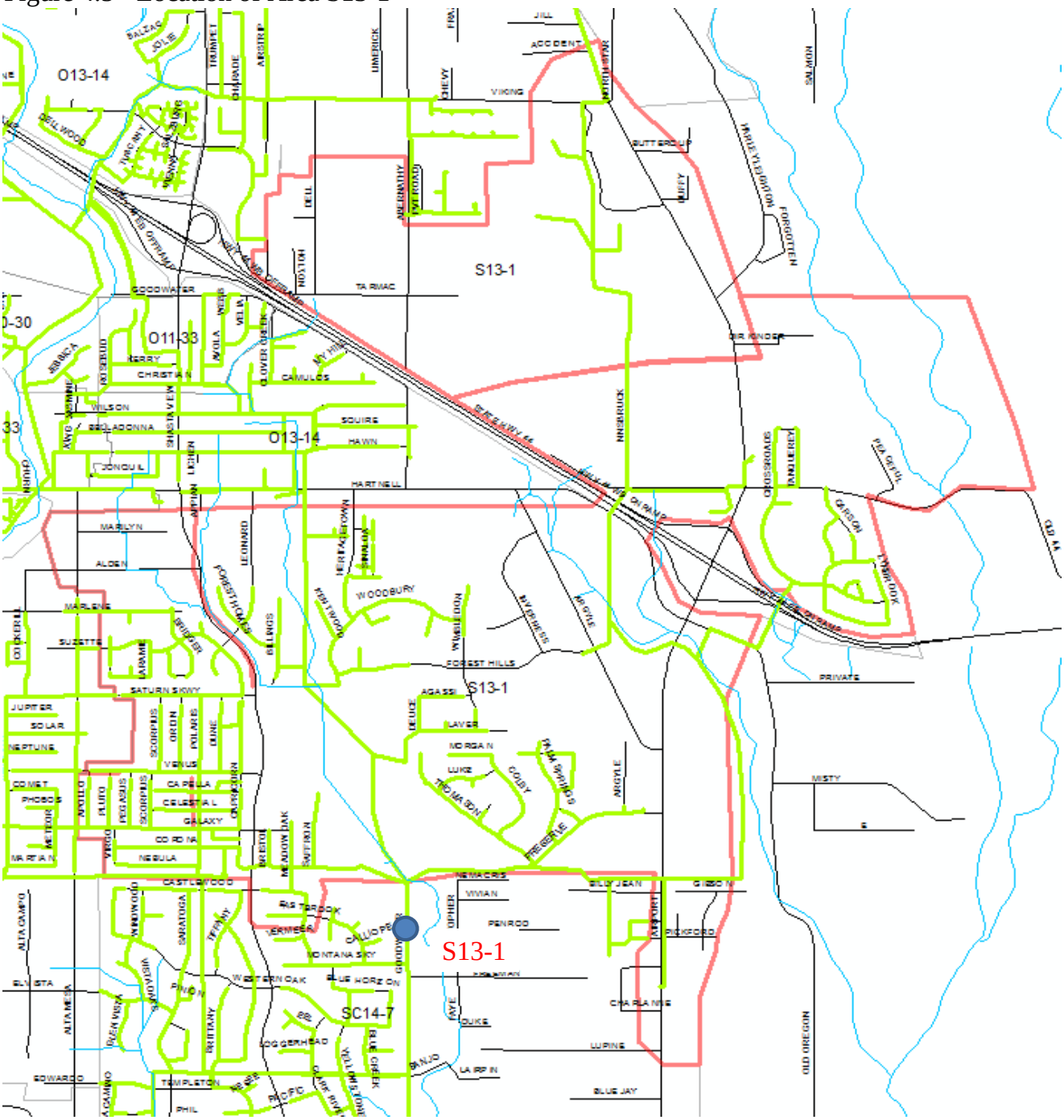


Figure 4.6 - Location of Area O13-14

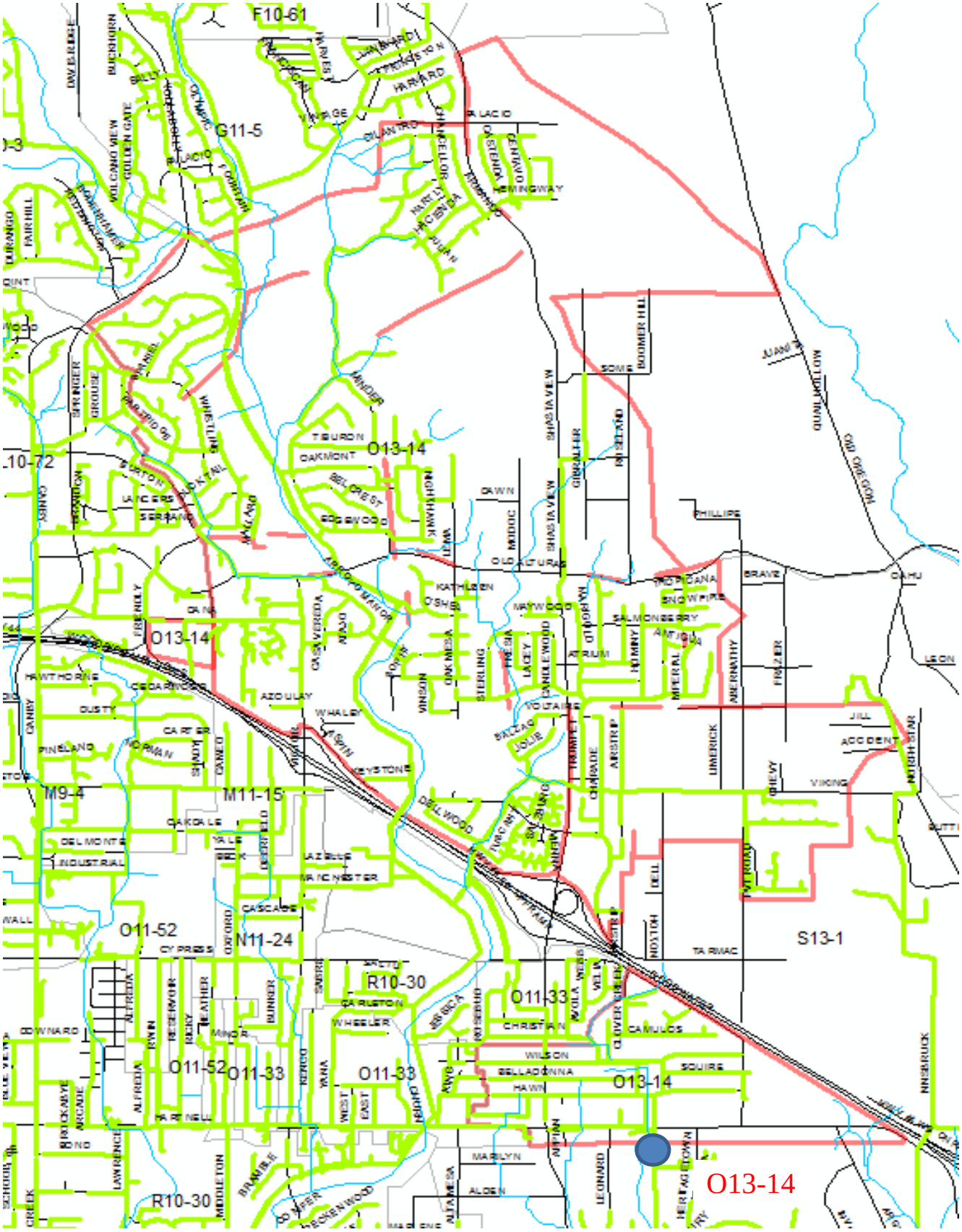


Figure 4.7 - Location of Area N11-24

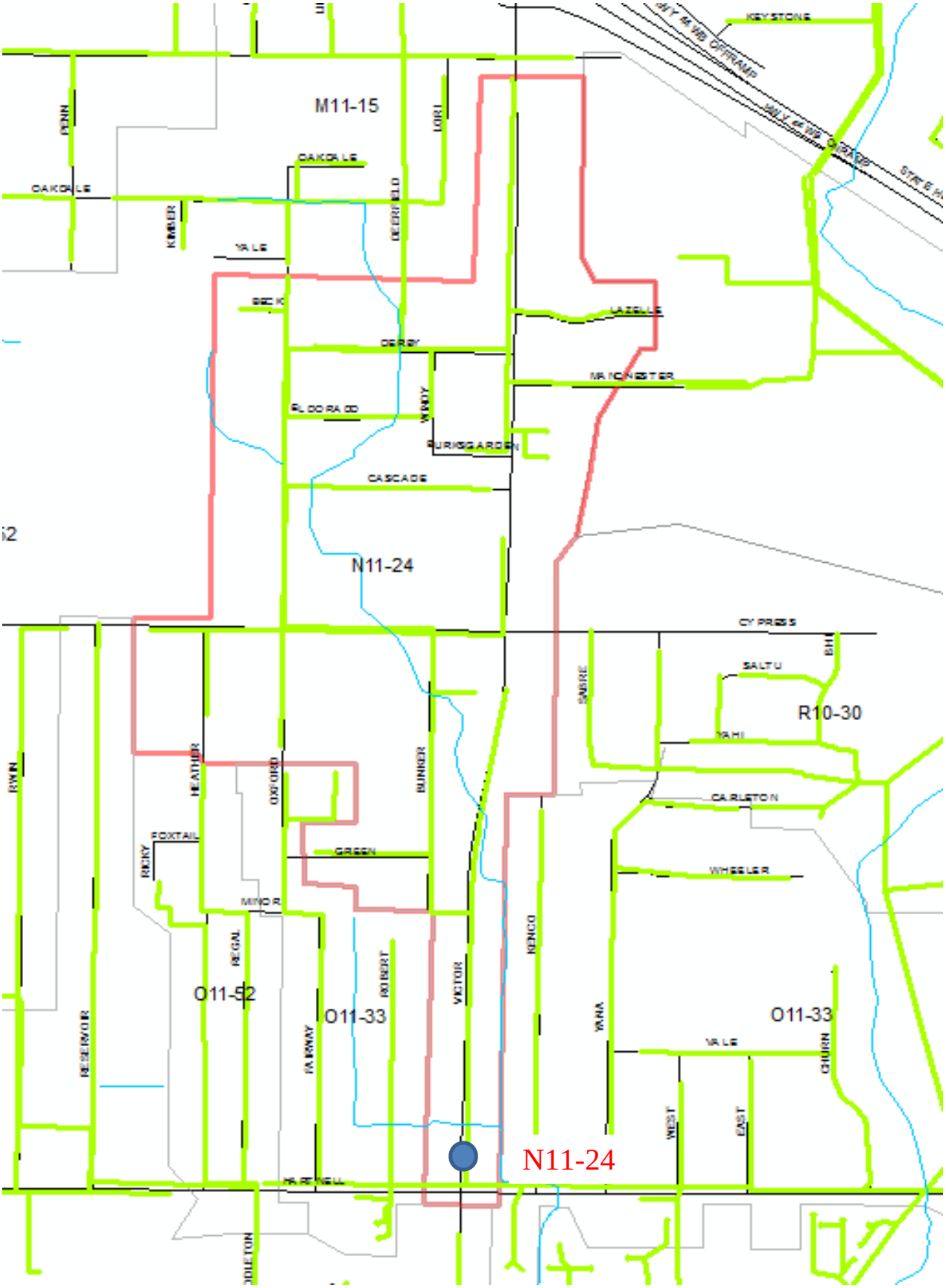


Figure 4.8 - Location of Area O11-33

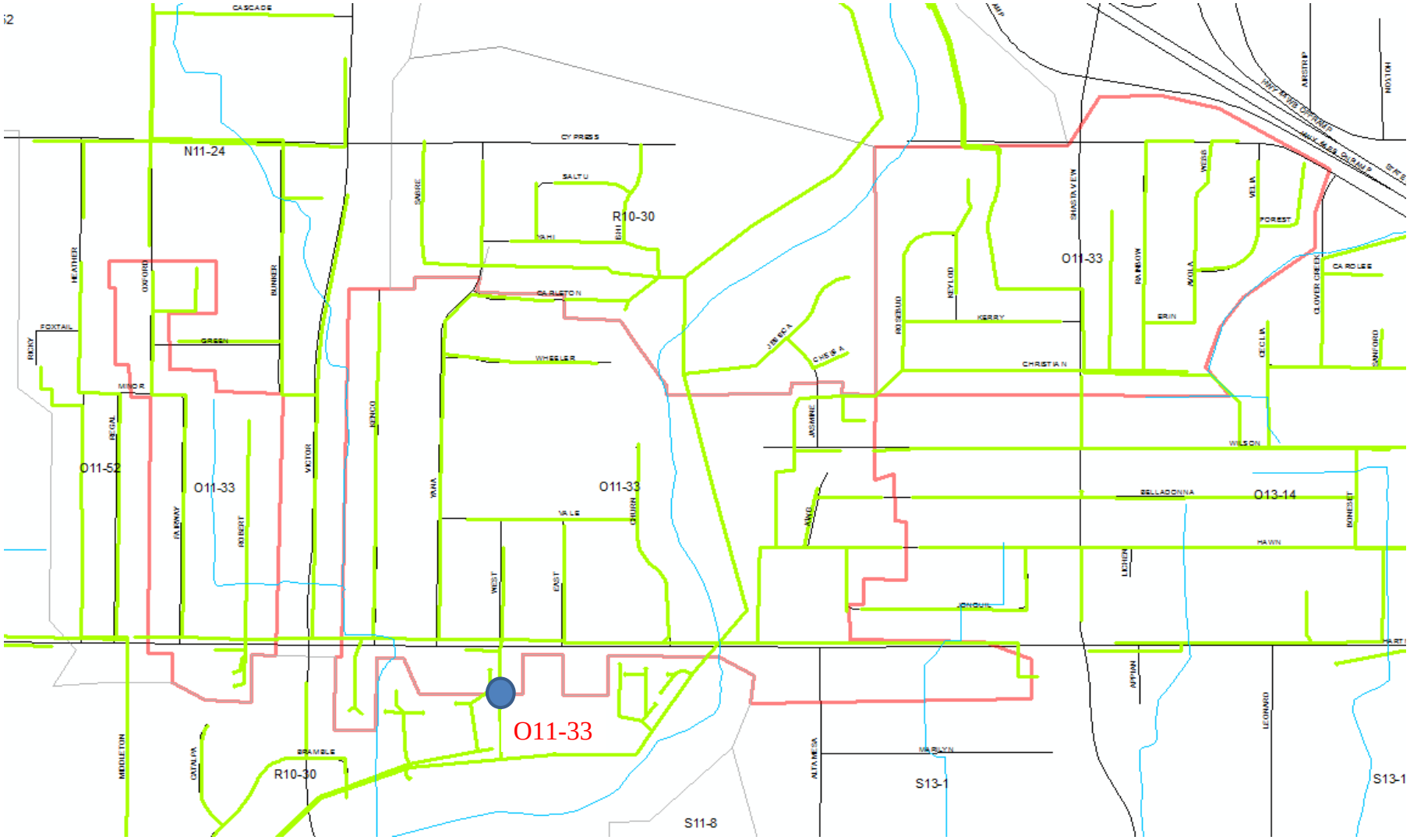
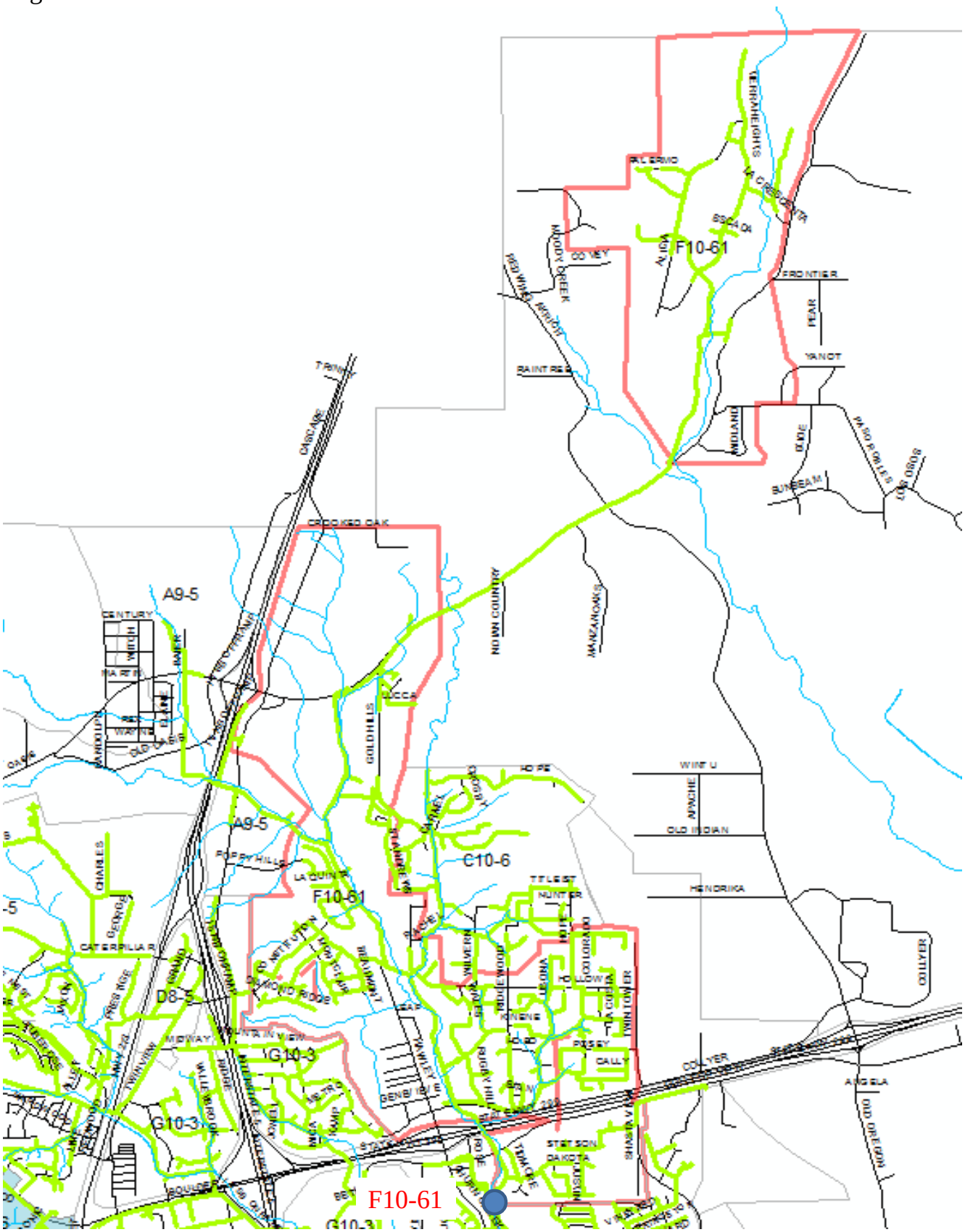



Figure 4.9 - Location of Area F10-61