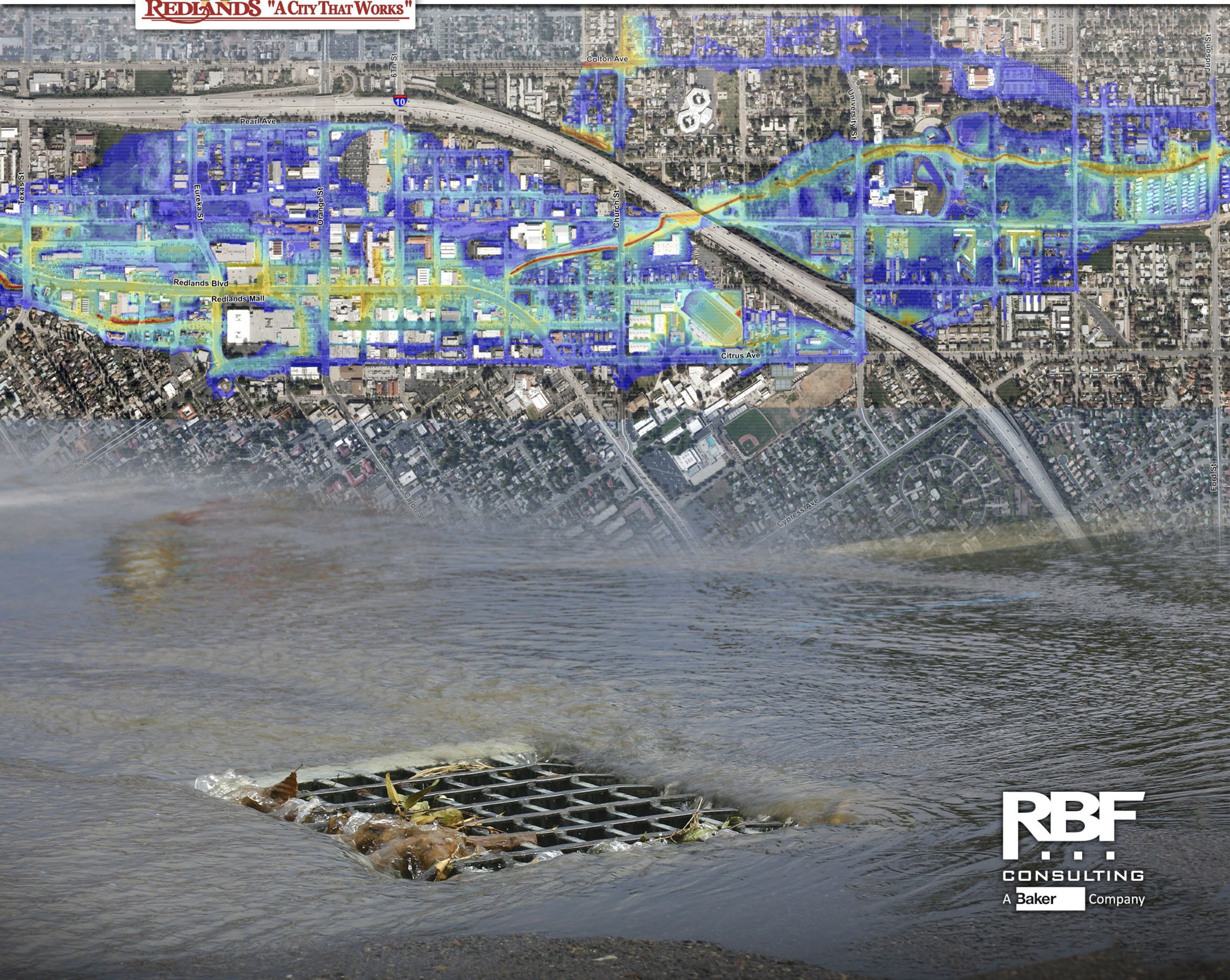
FINAL

CITY OF REDLANDS

Drainage Master Plan

May 15, 2014



CITY OF REDLANDS
MASTER PLAN OF DRAINAGE
San Bernardino County, California

Prepared for

City of Redlands
35 Cajon Street
Redlands, California 92373

Prepared by

RBF CONSULTING
A Baker Company
14725 Alton Parkway
Irvine, CA 92618

Contact Persons

Tom Ryan, RCE 61701
Tim Muli, RCE 72992
Mujahid Chandoo, RCE 76633
Daniela Mallot, EIT

May, 2014
RBF JN 136769 - 138509

This page intentionally left blank.

Table of Contents

Executive Summary iv

1 Introduction 1-1
- 1.1 Purpose 1-1
- 1.2 Background 1-1
- 1.3 Existing Watershed Description 1-2
- 1.4 Background Facility Inventory 1-7
- 1.5 Water Quality and Recharge Initiatives 1-8

2 Technical Criteria 2-1
- 2.1 Hydrologic Analysis 2-1
  - 2.1.1 Hydrology Criteria for Street Capacity Calculations 2-1
  - 2.1.2 Precipitation 2-2
  - 2.1.3 Land Use 2-2
  - 2.1.4 Soil Types 2-2
  - 2.1.5 Watershed Descriptions 2-3
- 2.2 Hydraulic Analyses 2-4
  - 2.2.1 Existing Conditions 2-5
  - 2.2.2 Proposed Conditions 2-6
- 2.3 Facility Priority Evaluations 2-9
- 2.4 Cost Estimates 2-9

3 Drainage Area Results 3-1
- 3.1 Mission Zanja Drainage Area 3-1
  - 3.1.1 Hydrologic Analysis 3-1
  - 3.1.2 Hydraulic Analysis 3-1
  - 3.1.3 Proposed Improvements 3-2
  - 3.1.4 Cost Estimates 3-3
- 3.2 Reservoir Canyon Drainage Area 3-3
  - 3.2.1 Hydrologic Analysis 3-3
  - 3.2.2 Hydraulic Analysis 3-4
  - 3.2.3 Proposed Improvements 3-4
  - 3.2.4 Cost Estimates 3-12
- 3.3 Downtown Drainage Area 3-12
  - 3.3.1 Hydrologic Analysis 3-12
  - 3.3.2 Hydraulic Analysis 3-13
  - 3.3.3 Proposed Improvements 3-17
  - 3.3.4 Cost Estimates 3-23
- 3.4 North City Drainage Area 3-24
  - 3.4.1 Hydrologic Analysis 3-24
  - 3.4.2 Hydraulic Analysis 3-24
  - 3.4.3 Proposed Improvements 3-25
  - 3.4.4 Cost Estimates 3-34
- 3.5 South City Drainage Area 3-35
  - 3.5.1 Hydrologic Analysis 3-35
  - 3.5.2 Hydraulic Analysis 3-35
  - 3.5.3 Proposed Improvements 3-36
  - 3.5.4 Cost Estimates 3-46

4 Capital Improvement Plan 4-48

5 Green Initiatives 5-1

6 Available Drainage Data/Material 6-1
6.1 Drainage As-Built Plans 6-1
7 Final Considerations and Future Recommendations 7-1

Figures

Figure 1-1: Vicinity Map 1-4
Figure 1-2: Location Map 1-5
Figure 1-3: Regional Watershed Map 1-6
Figure 2-1: Proposed Facilities Key Map 2-8
Figure 3-1: Zanja Area Proposed Facilities Maps 3-1
Figure 3-2: Reservoir Canyon Proposed Facilities Maps 3-6
Figure 3-3: Regional Alternative1 3-15
Figure 3-4: Regional Alternative 2 3-16
Figure 3-5: Downtown Area Proposed Facilities Maps 3-18
Figure 3-6: North City Proposed Facilities Maps 3-26
Figure 3-7: South City Proposed Facilities Maps 3-38
Figure 5-1: Green Initiatives 5-3

Tables

Table 1-1: Watershed Drainage Areas 1-3
Table 1-2: Hydrology Background Information 1-7
Table 2-1: Design Protection Levels for Streets 2-6
Table 3-1: Mission Zanja Drainage Area Hydrology Summary (AMC II) 3-1
Table 3-2: Mission Zanja Drainage Area Proposed Improvements 3-3
Table 3-3: Mission Zanja Drainage Area Cost Estimate Summary 3-3
Table 3-4: Reservoir Canyon Drainage Area Hydrology Summary (AMCII) 3-4
Table 3-5: Reservoir Canyon Drainage Area Proposed Improvements 3-5
Table 3-6: Reservoir Canyon Drainage Area Cost Estimate Summary 3-12
Table 3-7: Downtown Drainage Area Hydrology Summary (AMCII) 3-13
Table 3-8: Downtown Regional Alternative Estimated Cost Comparison Summary 3-17
Table 3-9: Downtown Area Proposed Improvements 3-17
Table 3-10: Downtown Drainage Area Cost Estimate Summary 3-23
Table 3-11: North City Drainage Area Hydrology Summary (AMCII) 3-24
Table 3-12: North City Drainage Area Proposed Improvements 3-25
Table 3-13: North City Drainage Area Cost Estimate Summary 3-34
Table 3-14: South City Drainage Area Hydrology Summary (AMCII) 3-35
Table 3-15: South City Drainage Area Proposed Improvements 3-36
Table 3-16: South City Drainage Area Cost Estimate Summary 3-46
Table 4-1: Priority 1a Cost Estimate Summary 4-48
Table 4-2: Priority 1b Cost Estimate Summary 4-48
Table 4-3: Priority 2 Cost Estimate Summary 4-49
Table 4-4: Priority 3 Cost Estimate Summary 4-49
Table 5-1: Green Initiative Sites Summary 5-2

Exhibits

Exhibit 1: County Hydrology Map (CDSP#4)
Exhibit 2: Downtown Hydrology Map
Exhibit 3: Storm Drain Facilities Idenfication Map
Exhibit 4: Main Stormdrain Facilities - Proposed Priorities Map

Technical Appendices

Appendix A: Hydrology (CD)
- A.1 – Rational Method County Files (AMC II) - 100-, 25-, 10-year
- A.2 – Rational Method County "Modified" Files - 100-, 25-, 10-year
- A.3 – Opal Basin Hydrology (AMC II) 100-year
- A.4 – Downtown Area Hydrology

Appendix B: Hydraulics
- B.1 – WSPGW Hydraulic Calculations (Main Storm Drain Lines)
  - Existing Capacity
  - 25-Year Proposed Conditions
- B.2 – Normal Depth Calculations (Collector Storm Drains)
  - Existing Capacity
  - 25-Year Proposed Conditions
- B.3 – Flooded Width Analysis (Excel)
  - Proposed Conditions (10-, 25-, 100-Year)
- B.4 – XP-SWMM Analysis
  - Model Methodology & Procedures
  - Regional Alternative Exhibits
  - Downtown Local Storm Drain Tables

Appendix C: Cost Estimates
- C.1 Detailed Cost Spreadsheets
- C.2 Costs Per Watershed
  - Mission Zanja Costs
  - Reservoir Canyon Costs
  - Downtown Costs
  - North City Costs
  - South City Costs

Appendix D: Storm Drain Priority Rankings
Appendix E: Green Initiatives

Executive Summary

The City of Redlands has a long history of flooding during moderate to severe storm events. Causes of the flooding include both local and regional storm drain deficiencies. The main cause of the flooding is a lack of conveyance capacities in the Mission Zanja (Zanja), Redlands Boulevard storm drain, and the Oriental storm drain. With a capacity of approximately 2,400 cfs, the Redlands Boulevard storm drain receives over 4,200 cfs from Zanja and the Carrot storm drain and 4,000 cfs from Reservoir Canyon and the Oriental storm drains. All four of these tributaries confluence near the Redlands Boulevard and 9th Street intersection.

Over the past three decades, the focus of several studies has been on reducing the flood potential from the Zanja and Reservoir Canyon. Several alternatives have been investigated and proposed, ranging from multiple detention basins, to a downtown "bypass" structure that would direct Zanja flows around the Redlands Boulevard storm drain. Due to the physical characteristic of the Reservoir Canyon watershed, no feasible flow mitigation solutions were identified. The Zanja bypass structure has been conceptually evaluated by the U.S. Army Corps of Engineers (USACE), and planned by BSI Consultants and TKE Engineering.

From the results and findings of previous studies performed by the City and the County, a proposed detention basin located along the Zanja at Opal Street was identified as a feasible option for reducing peak flows in the Zanja watershed. Design plans for the Opal basin are currently being prepared by TKE for the City. Based on previous cost estimates, this facility will cost $15 million to implement.

Regional Flooding Analysis

As part of this study, RBF evaluated the City's planned diversion structure, or downtown bypass pipeline storm drain in conjunction with the proposed Opal Basin to identify if the system was hydraulically effective in eliminating flooding in the City. Using an advanced hydraulic modeling approach, this planned system was evaluated and compared to other potential alternative solutions to the downtown regional flooding issue.

The downtown area, in addition to a portion of Zanja (upstream of the I-10), was evaluated using XP Software's XP-SWMM, which is an improved version of the U.S. EPA's Storm Water Management Model (SWMM). XP-SWMM is a dynamic wave model that solves the full St. Venant Equations. Dynamic modeling allows the effects of storage and backwater in conduits and floodplains and the timing of the hydrographs to yield a true representation of the hydraulic conditions. XP-SWMM can model the surface in 2-dimensions, while linking to the subsurface infrastructure, or storm drain system. The result is a comprehensive model that can communicate between the surface and subsurface facilities throughout the modeled design storm duration.

Based on the results of the advanced model, the planned bypass system would fail at several locations. Due to the peak flows from the Reservoir Canyon watershed, the existing Redlands Boulevard storm drain exceeded capacity, regardless of how much flow was diverted from the Zanja. If this planned system were to be implemented successfully, the Redlands Boulevard storm drain would also have to be improved, or a large portion of the flows from Reservoir Canyon would need to be diverted to the Zanja bypass as well.

RBF performed several alternatives and identified two that would reduce the downtown flooding to an acceptable level; 1) Increase Redlands Boulevard storm drain capacity; and 2) Bypassing the entire Zanja and a portion of Reservoir Canyon, around the downtown Redlands Boulevard storm drain. Both alternatives would consist of multiple construction issues, but it was found that the required size of the bypass (Alternative 2) would require more right-of-way than what is available. Several buildings have been constructed along the existing easement for the planned bypass. The required construction footprint of the identified Alternative 2 greatly exceeds the distance between these structures. For example, in a few locations along the proposed alignment, the distance between buildings is as little as 26 to 30 feet. The identified bypass facility (double 12'w x 8'h box) would have a structure width of approximately 27 feet. This would make it impossible to construct the proposed double reinforced concrete box within that easement.

Alternative 1 is the recommended alternative. It utilizes the existing facility by adding a parallel reinforced concrete box (RCB) next to it. The existing facility is a 12-foot wide by (7 to 8-feet) high. This proposed alternative includes the addition of a 15-foot wide by 9-foot high box adjacent to existing structure along the main portion of Redlands Boulevard. A secondary split occurs near 3rd Street, where a new double 12'w x 8'h RCB is proposed to continue down Redlands Boulevard to Texas Street.

Alternative 1 does have some construction issues. The main issue will be the traffic control along Redlands Boulevard. Access to the businesses along the proposed alignment may be difficult during the construction. Existing utility impacts could also be an issue. Although utility locations were unknown at the time of this study, it is estimated that several exist within the street.

The estimated costs for just these regional alternative facilities are shown in Table E-1. These costs include the necessary improvements to the main Redlands Boulevard storm drain, and/or the downtown bypass channel. For comparison purposes, only the differences in the regional drainage structures were considered for the two alternatives. All other local storm drain improvements that would be necessary for both alternatives were not included.

Table E-1: Isolated Regional Alternative Cost Comparison

Regional Alternative	Isolated Construction Cost
Alternative 1	$ 14,100,000
Alternative 2	$ 17,100,000

These values do not represent an absolute cost, but rather a relative cost with respect to their proposed facility size. Consequently, these costs do not include other contingencies that could be included in the comprehensive implementation. For detailed drainage costs, refer to Section 3.

Local Master Planned Facilities

The City, and its tributaries, was divided into five main watersheds: Mission Zanja; Reservoir Canyon; Downtown; North City; and South City. Only the City-owned drainage facilities within the City boundary were included in this study, except for the Northwest Redlands area (Figure 1-3). These facilities (owned by the County) were also included in this study. A small portion of the facilities located along the San Timoteo Channel were not included in this study.

The facilities were evaluated based on the watershed they reside in. Within each watershed "project areas" and "facility identifications" were established based on the existing County's CSDP#4 report identification system. The proposed facility costs are summarized in Table E-2 below based on watershed.

Table E-2: Storm Drain Facility Cost Summary per Watershed

Watershed	Project Areas	Cost
Mission Zanja	27, Opal Basin	$18,740,000
Reservoir Canyon	22, 25, 26	$16,510,000
Downtown	21,22	$10,210,000
North City	6,7,8,9,10	$20,050,000
South City	17,18,19,37,38,39,40,41	$18,070,000
TOTAL:		**$83,580,000**

1. Based on previous estimates.
2. Includes portion of the "Regional Alternative 1" proposed facility.

As a part of this Master Plan of Drainage (MPD), RBF evaluated the existing capacity of the regional and local storm drain facilities within the City of Redlands. Using the recently updated hydrology in the Comprehensive Storm Drain Plan #4 (CDSP#4) report, completed by San Bernardino County Flood Control District in February of 2013, RBF identified proposed storm drain facility sizes to alleviate excessive flooding. A priority ranking system was developed based on the existing capacity and the proposed storm drain system required to convey the design level the 10-, 25-, and 100-year storm events.

The priority ranking was developed based on the projects of greatest importance. A process has been prepared to determine which projects should be constructed first when funding becomes available. The three priorities are summarized below:

- **Priority 1a (*highest priority*)**
  - *Local Streets* – Existing streets and storm drain systems where flood depth is above the right-of-way in the 10-year storm event.
  - *Arterial Streets* - Existing streets and storm drain systems where flood depth is above the right-of-way in the 25-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 10-year flood protection AND overflows impact multiple adjacent local facilities.
- **Priority 1b**
  - *Local Streets* – Existing streets and storm drain systems where flood depth is above top of the curb in 10-year storm event.
  - *Arterial Streets* **-** Existing streets and storm drain systems where flood depth is above top of curb in the 25-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 25-year flood protection AND overflows impact multiple adjacent local facilities.
- **Priority 2**
  - *Arterial Streets* **-** Existing streets and storm drain systems where flooded width is greater than 17 feet in the 10-year storm event.

  - *Regional Facilities* – Existing storm drain systems do not achieve 100-year flood protection AND overflows impact multiple adjacent local facilities.
- **Priority 3**
  - *Local Streets* – Existing streets and storm drain systems where flood depth is above the right-of-way in the 100-year storm event.
  - *Arterial Streets* **-** Existing streets and storm drain systems where flood depth is above the right-of-way in the 100-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 100-year flood protection AND overflows impact multiple adjacent local facilities.

Using this ranking system, each project area, or system, was ranked in terms of deficiency. This information is presented to the City to aid in the decision process of identifying where to allocated funding for immediate needs projects.

Table E-3: Priority Ranking Facility Cost Summary

Priority Ranking	Cost
Priority 1a	$40,190,000*
Priority 1b	$30,710,000
Priority 2	$2,530,000
Priority 3	$10,150,000
TOTAL	**$83,580,000**

**Note: Priority 1a includes Opal Basin ($15,000,000)*

Green Initiatives

As part of this Master Plan of Drainage, water quality and water replenishment initiatives were identified and evaluated. In accordance with the requirements of the Santa Ana RWQCB Permit No. R8-2010-0036, the City is to establish a review, approval and permitting process for new development and redevelopment occurring within its boundaries.

This MPD includes potential applications for redevelopment and retrofitting existing drainage facilities to accommodate water quality treatment and/or groundwater replenishment. Ten (10) locations were identified for "Green Initiatives" based on location, soil type, land use, and tributary drainage area size (Table E-4). The locations of the site are illustrated on Figure 5-1.

Table E-4: Green Initiative Sites Summary

Site No.	Drainage Area (acres)	Recommended Facility (BMP)	Notes
1	560	Infiltration Basin/Underground Storage	Two potential sites adjacent to each other.
2	34	Bioretention	Treatment of existing parking lot.

Site No.	Drainage Area (acres)	Recommended Facility (BMP)	Notes
3	98	Infiltration Basin	Located in existing drainage area.
4	5,400	Infiltration Basin	Site tentatively accepted by University of Redlands.
5	41	Infiltration Basin/Underground Storage	Site adjacent to Reservoir Canyon storm drain.
6	4,030	Infiltration Basin	Future planned Opal Basin
7	57	Underground Infiltration/Bioretention	Future Walmart site.
8	10,100	Infiltration Basin	Jenny Davis Park adjacent to channel.
9	28	Infiltration Basin	Existing park site with large potential site area.
10	58	Infiltration Basin	Located in existing drainage area.

These Green Initiatives have been identified as some of the best potential locations for effective ground water recharge. Further evaluation of these sites would include detailed geotechnical investigations, property owner coordination, and land use evaluation. Proper installation, operation, and maintenance of these types of facilities are paramount to their effectiveness and longevity. Although these sites have been identified as the best suitable locations for “green” infrastructure, the facilities identified as part of the MPD flood control plan can be further evaluated for potential “green” infrastructure during the design phase.

1 Introduction

1.1 Purpose

The City of Redlands Master Plan of Storm Drainage covers the City and adjacent areas that are tributary to the major regional flood control facilities that traverse through the City. The purpose of the Master Plan is to:

- Provide comprehensive long-range planning for the implementation and development of drainage facility improvements in the area,
- Determine the cost of implementing the facilities, and
- Discuss funding priorities of the improvements.

Since the City of Redlands does not have a Design Manual for Drainage Facilities, the County of San Bernardino standards were used as a basis for the criteria used in this Master Plan of Drainage.

Figures 1-1 and 1-2 show the existing Regional Location Map and Project Location map, respectively.

1.2 Background

The City of Redlands does not currently have a Master Plan of Drainage (MPD) specifically devoted to their drainage system and City needs. The City uses the San Bernardino County Flood Control District's (SBCFCD) "Zone 3 Comprehensive Storm Drain Plan No. 4" (CSDP#4), and historical flood events to help identify current and future drainage improvement needs. Originally prepared in 1976, a later revision to the CSDP#4 hydrology section was prepared by the County in February of 2013. No updates have been performed for the hydraulics or facility sizing with the revision to the hydrology. The intent of this Master Plan is to use the County's latest hydrology to identify the appropriate drainage facility infrastructure to provide appropriate flood protection.

The City of Redlands has a long history of flooding during moderate to severe storm events. One of the main causes for flooding is the lack of conveyance capacity in the historical channel of Mission Zanja (Zanja). The Zanja, formerly known as the Mill Creek Zanja, is a surface channel that flows from the Crafton Hills area, west to 9th Street, near downtown Redlands, where it transitions into a box culvert. The Zanja was built by the natives in 1819 as a water-supply irrigation ditch, pulling flows from Mill Creek. Due to extensive flooding and development, the diversion of flow from Mill Creek was blocked. Nonetheless, the Zanja was never improved to convey local storm flows and the drainage area tributary to the 9th Street storm drain still produces flows that far exceed the capacity of the box culvert, causing extensive flooding through the downtown area. The City has secured funding for the implementation of a flood attenuation basin along the Zanja, at Opal Avenue (Opal Basin).

Another source of flooding comes from the Reservoir Canyon storm drain. Several previous studies have been completed to try and identify potential attenuation solutions, with no successful site location.

Other efforts to minimize the flooding in downtown Redlands include a proposed diversion pipe that would split flows from Zanja at 9th Street. As part of the effort to identify drainage facility sizing, this alternative will be reviewed.

In addition to the County's 1976 CDSP#4 and their hydrology update prepared in February 2013, other studies that were reviewed and used as reference in this study include the following:

- Crafton and Opal Detention Basins Feasibility Study, Volume 1 – 2009, SBCFCD
- City of Redlands Field Investigation Report – 2009, SBCFCD
- Mill Creek Zanja Detention Basin Study, SBCFCD – 1986, Williamson & Schmidt
- FEMA FIS Study Yucca Creek, The Zanja – 1976 (approximately), FEMA
- Mission Zanja Creek, City of Redlands San Bernardino County, 1986, USACE.

1.3 Existing Watershed Description

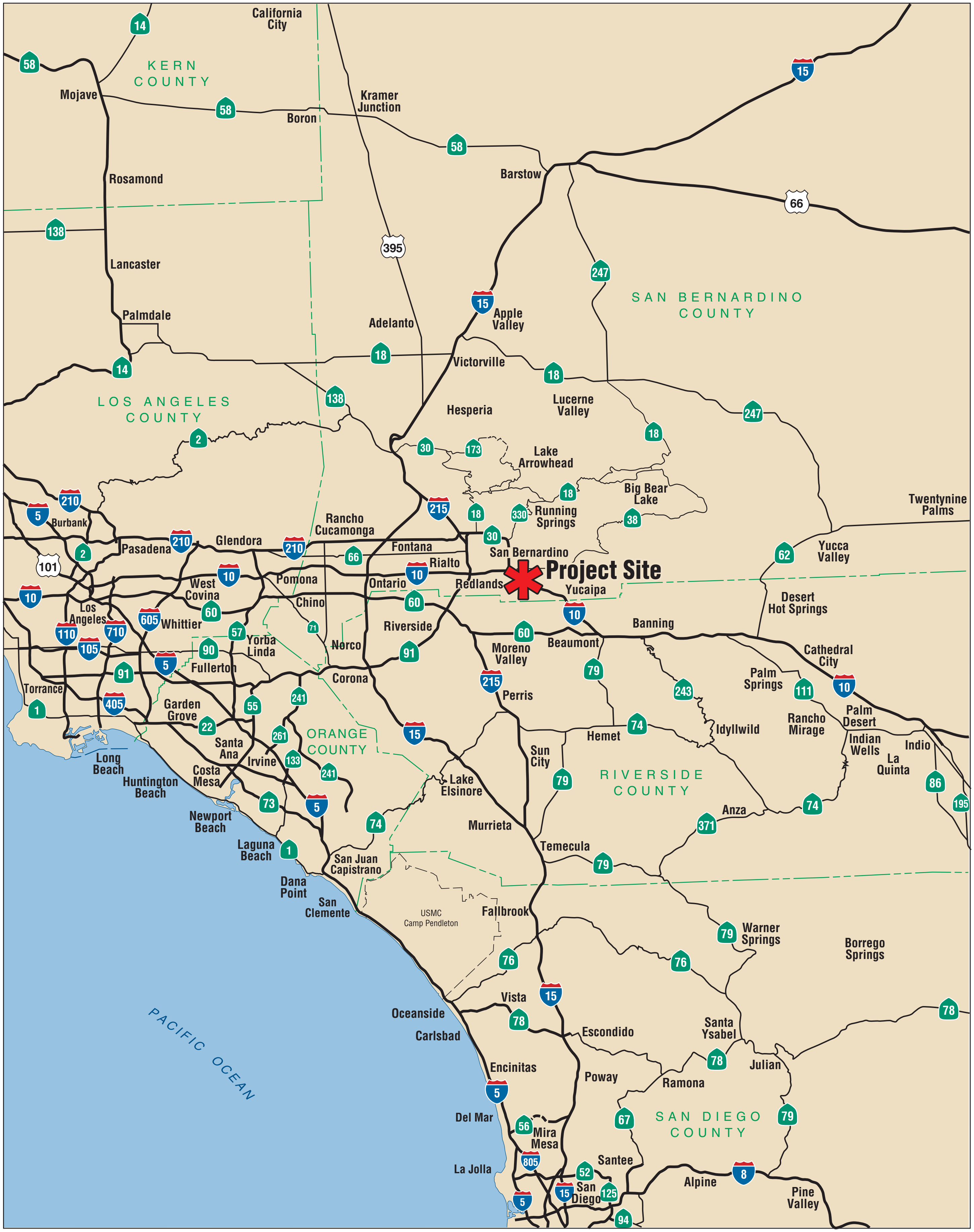
The City of Redlands generally drains from east to west to one of two main existing major flood control facilities. These facilities include the Santa Ana River and the San Timoteo Channel. Tributary to these major flood control facilities are several tributaries that run through the City of Redlands. Three of the largest named tributaries are: Mission Zanja, Reservoir Canyon Channel, and Mission Channel. The downtown area of the City of Redlands is located at the confluence of the historical Mission Zanja (Zanja) and the Reservoir Canyon Channel nears the east end. Downstream, at the northwest side of downtown, these flows combine with other local tributaries to form the Mission Channel.

Tributary to the downtown area, the Zanja consists of approximately 6,000 acres of drainage area. The Reservoir Canyon Channel consists of about 4,000 acres of drainage area tributary to the confluence with the Zanja at Redlands Boulevard. Other tributaries contribute to the downtown include the Oriental storm Drain (1000 acres) and the Carrot storm drain (543 acres).

This study is intended as a planning level investigation to determine current development and potential future redevelopment impacts to hydrology sizing of the proposed drainage infrastructure. The analyses were performed to cover the drainage areas within the City of Redlands. The Area designations or Regional Watershed Areas are listed below, and illustrated in Figure 1-3.

Table 1-1: Watershed Drainage Areas

Drainage Area Designation	Description
Mission Zanja	Covers drainage area tributary to Zanja to the confluence with Reservoir Canyon storm drain at Redlands Boulevard storm drain.
Reservoir Canyon	Covers the drainage area tributary to Reservoir Canyon storm drain to the confluence with Zanja at Redlands Boulevard storm drain.
Downtown	Covers local drainage area tributary to downtown (Redlands Boulevard) storm drain.
North City	Covers drainage area generally north of I-10 freeway, tributary to the Santa Ana River.
South City	Covers drainage areas in the far south of the City, tributary to Mission Creek and San Timoteo Creek.



RBF
A Baker Company

4/1/14 JN 138509-20104 MAS

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

Regional Vicinity

Figure 1-1

Source: Aerial Google Earth Pro.

0 1 2 miles

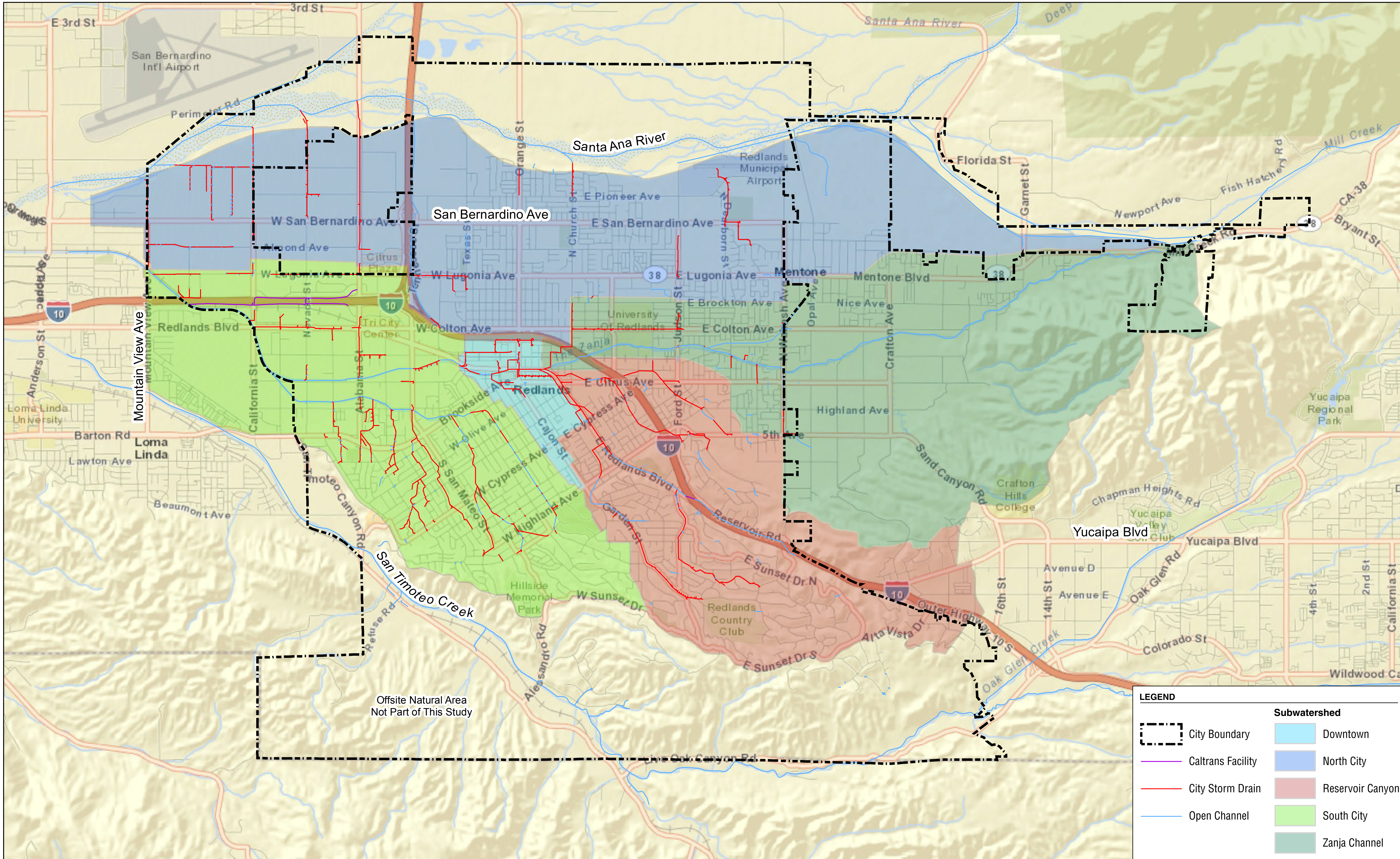
RBF A Baker Company

4/2/14 JN 138509-20104 MAS

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

Local Vicinity

Figure 1-2



CITY OF REDLANDS MASTER PLAN OF DRAINAGE

Drainage Area Map

Figure 1-3

RBF A Baker Company

4/7/14 JN 138509-20104 MAS

1.4 Background Facility Inventory

After compiling all available as-built data, GIS data, and reports, it was apparent that multiple information "gaps" existed in the local drainage system. Current as-built inventory covers approximately 30 percent of the existing city-wide drainage system. To improve accuracy of the hydraulic calculations and hydrologic boundary estimations, coordination with the City was necessary to acquire field verification of the existing storm drain facilities.

In some cases, these facilities were inaccessible, requiring engineering judgment to estimate approximate existing facility sizes, depths, and slopes. In most cases, upstream and downstream as-built plans were used to make determinations. If insufficient data existed, conduit slopes were estimated based on existing ground surface gradients.

Once the database was complete, the information was uploaded to GIS. The GIS database was used to help establish hydrologic drainage boundaries and to compile input data for hydraulic modeling of the existing storm drain capacities. The data collected in the field was used to back check the data from the as-builts, and the City's previous GIS database of the drainage facilities.

Table 1-2: Hydrology Background Information

Base Data	Source	Model Use
Topography	Flown 2014 (Downtown) Dated 2013 provided by SBCFCD (remaining City)	Primarily for elevations and slopes used in the XP-SWMM surface 2D models, AES rational and Unit Hydrograph analyses. Together with the As-built plans, provided the general slope of the area and was applied in determining tributary areas.
As-builts	City As-builts for storm drains and streets	Primarily for elevations and slopes of streets and storm drains hydraulics and also in hydrology to determine tributary areas.
Hydrologic Soil Types	SBCFCD CDSP#4 Updated Report (2013)	The soil data was used in the model was predominately Type "B" which has Moderate infiltration rates.
Land Use Data	SBCFCD CDSP#4 Updated Report (2013), verified w/ Aerial photo	Used as the basis for the land use determination. The data was then further refined with the aerial photography. The study area consists mainly of Commercial/Industrial and Residential land uses.
Aerial Photography	December, 2013	Used to further refine the City's Land Use Data into Land use types in accordance with the SBCFCD Hydrology Manual. Ex. Residential was refined into 5-7 dwelling units/acre (du), and apartments.

1.5 Water Quality and Recharge Initiatives

As part of this Master Plan of Drainage, water quality and water replenishment initiatives were evaluated. In accordance with the requirements of the Santa Ana RWQCB Permit No. R8-2010-0036, the City is to establish a review, approval and permitting process for new development and redevelopment occurring within its boundaries.

This MPD includes potential applications for redevelopment and retrofitting existing drainage facilities to accommodate water quality treatment and/or groundwater replenishment. Ten (10) locations have been identified for “Green Initiatives” based on location, soil type, land use, and tributary drainage area size.

Water quality facilities are designed to treat the “first flush”, or the smaller more frequent rainfall events. However, water quality facilities are not capable of treating or handing large flow events. Some volume based best management practices (BMPs) are capable of treating larger area, such as extended detention basins, retention basin, or large wetlands. Yet even these facilities cannot treat larger storm events. Combined flood control detention basins can be designed to treat water quality as well, but the treatment mechanism in the water quality portion of the basins will only treat the “first flush” storm events.

Low impact development (LID) strategies are encouraged in the NPDES Permit. The idea of disconnecting impervious surfaces leads to “first flush” or small storm partial infiltration. This could be beneficial for new development or redevelopment with respect to slowing the local drainage “Time of Concentration” to produce lower peak flows during small storm events. With respect to large storm events, generally over 2-year storm events, these “impervious” areas or water quality features are already at capacity and unable to accept any additional flows.

A comprehensive study of the City’s drainage areas has been performed to identify potential areas for Green Initiatives, or combined water quality/ground water recharge facilities. To maximize the facility benefits, large open space areas (for facility footprint) with a sizable drainage tributary area were evaluated. In some cases, smaller areas were also considered based on land use and potential to treat large paved or impervious areas.

2 Technical Criteria

2.1 Hydrologic Analysis

The County's updated CSDP#4 report used the original hydrologic boundaries from the 1975 CSDP#4 report. As a result, they were not updated based on the City's current storm drain system layout. These boundaries have been updated to match the existing and proposed storm drain system layout. However the regional boundaries identified from the updated CSDP#4 were used for this study.

The directive of this MPD is to use the updated County hydrology values where possible to identify appropriate flood control measures and drainage infrastructure to reduce flooding within the City. Consequently, the drainage facilities have been identified based on the previous CSDP#4 naming conventions.

Where new hydrology needed to be created, the hydrology analysis was achieved using the rational method model and multiple unit hydrograph method models for all concentration points where the total tributary area exceeds 640 acres. This was done for the 10-year, 25-year, and 100-year storm events, where the County's CSDP#4 report results were recalculated. The analysis was conducted per the SBCFCD Hydrology Manual and methods discussed below.

For the purpose of the advanced surface modeling within the downtown area, the County hydrology was used as a basis to develop peak flow hydrographs for the 100-year storm events. The local storm drain systems directly tributary to the Redlands Boulevard storm drain, were evaluated individually. Each local area required individual unit hydrograph development to appropriately evaluate flooding potential.

The updated County hydrology was reviewed to ensure appropriate hydrologic characteristics were used in the development of peak runoff. In one instance, the area tributary to the proposed Opal Basin was revised to include more realistic Manning's "n" values within the reaches of the Zanja. Using a Manning's "n" value that corresponded to "improved" channels sections, the County assumed this reach would be built out. Due to the historic value of this creek, it was assumed that existing, "natural" Manning "n" values would be more appropriate.

2.1.1 Hydrology Criteria for Street Capacity Calculations

The 10-year, 25-year, and 100-year peak flows were applied in street flooded width analysis to meet the following criteria for local streets and arterial highways:

Local Streets

1. The 10-year storm on sloped streets and 25-year storm for sump condition (where the area in question is at a low point, water surface elevation shall not exceed top of curb).
2. The 100-year water surface elevation shall not exceed the street right-of-way.

Arterial Highways (Major Roadways)

1. One travel lane (12-foot assumed if not determined) shall be free from inundation in each direction in a 10-year storm.
2. In a sump condition, one travel lane (12-foot assumed if not determined) shall be free from inundation in each direction in a 25-year storm.

3. The 100-year water surface elevation shall not exceed the street right-of-way.

Areas where recalculation of hydrology was necessary within the interior of the downtown region, the following SBCFCD Rational Method Guidelines, as outlined in their Hydrology Manual, were applied for the Rational Method analysis:

- Initial area maximum distance did not exceed 1,000' and was based on sheet flow only.
- Initial subareas were less than 10 acres.
- Subarea sizes increased gradually to satisfy the following conditions for 100-year calculations:
    - Travel Times increase by less than 3 minutes when TC is less than 30 minutes
    - Travel Times increase by less than5 minutes when TC is less than 60 minutes
    - Travel Times increase by less than10 minutes when TC is over 60 minutes

Most of the City streets are extremely flat, and in a few instances, this criterion was slightly exceeded. This was based on engineering judgment and eliminated breaking down the subareas and flow lengths further than necessary for this planning-level analysis.

Hydrologic routing for both rational and unit hydrograph analyses were performed utilizing the existing facility sizes provided by the City and Manning's "n" values were estimated based on San Bernardino County Flood Control Design Manual guidelines. AES Computer Software was used to estimate initial storm drain sizes, where existing system sizes were unknown or are non-existent.

The Rational Method times of concentrations were used to calculate lag times, while the land use and soil type parameters were applied in determining the sub-watershed and watershed loss rates. Both the lag times and loss rate are necessary for unit hydrograph analysis.

2.1.2 Precipitation

The precipitation values used in the County's CSDP#4 Hydrology Update in 2013 were in compliance with the 1986 Hydrology Manual. These values have changed since the previous 1976 CSDP#4 report. The hydrology models were performed using the 24-hour duration, 10-, 25-, and 100-year storm event precipitation values. For master planning purposes, the County used an Antecedent Moisture Condition value of 2 (AMC II). For detailed precipitation amounts, refer to the 2013 CSDP#4 Hydrology update, or the County's Hydrology Manual.

2.1.3 Land Use

Land Use designations were acquired from the County CDSP#4 report values. For local areas within downtown that required new hydrology to be calculated, CDSP#4 values were compared to General Plan values. In the downtown area, some of the CSDP#4 watershed had to be refined to adequately identify minor drainage area contributions to the main Redlands Boulevard storm drain.

2.1.4 Soil Types

The soil data used was consistent with those found in the County CSDP#4 calculations. The soil types within the City consisted predominantly of Type "B" which has moderate infiltration rates. The values in the CSDP#4 were developed based on the County Soils maps.

2.1.5 Watershed Descriptions

The watersheds tributary and within the City, were divided into five (5) areas; Mission Zanja (Zanja), Reservoir Canyon, Downtown, North City, and South City. The Zanja and Reservoir Canyon watersheds comprise of most of the area tributary to the City, and thus most of the flood source potential for the downtown area. Refer to Figure 1-3, "Regional Watershed Map."

The Zanja is the largest watershed tributary to the downtown area, consisting of 6,000 acres. The area includes the Crafton Hills area which is mostly flat agricultural lands and the area tributary to the Carrot storm drain, along Church Street. This area is mostly comprised of drainage area (approximately 4,000 acres) outside the City limit boundary. Consequently, this particular watershed has been extensively studied by the SBCFCD to identify possible flood control solutions. Current plans for flood control mitigation in this watershed include the implementation of the "Opal Basin." Another flood control project that has been identified is the construction of a diversion storm drain that would intercept flows at 9^{th} Street and Zanja and route them west to Texas Street, where it would join Mission Creek, essentially bypassing the downtown area.

The Reservoir Canyon watershed is the second largest watershed area tributary to downtown Redlands (approximately 4,000 acres tributary to 9^{th} Street). This area includes the Oriental storm drain tributary. Studies have been completed for this area to try and identify potential flood control mitigation efforts. The area is hilly, with relatively steep slopes. Consequently very little open space exists for potential detention/retention alternatives. Previous studies have shown no cost effective solutions for flood control attenuation is available for this area. This area is one of the main contributors to the historical flooding of the downtown area. With the proposed construction of the Opal Basin, and the planned diversion storm drain along the Zanja, it is expected that flows from this area will still cause extensive flooding in the downtown area.

The Downtown watershed consists of the local drainage systems in the downtown area, tributary to the Mission Creek channel at Alabama Street. Bound by the I-10 freeway to the north and Zanja and Reservoir Canyon to the east, and approximately Orange/Pine Avenue to the south, this area primarily consists of primarily dense residential and commercial development.

The North City watershed is the area north of the I-10 Freeway, and south of the Santa Ana River. This area is not tributary to the downtown area. This watershed is relatively flat, and is comprised of predominately agricultural and industrial land uses. The construction of Seven Oaks Dam has mitigated the flooding potential for the northern portion of this area, adjacent to the Santa Ana River. However, the Seven Oaks Dam does not affect the flooding potential of the downtown area.

The South City watershed consists of the drainage area south of downtown, tributary to Mission Creek. This area consists of hillside, residential, and open space. Existing storm drains and drainage courses in this area do not necessarily follow the alignments of the existing roads, but rather meander through the open space as "open channels." Areas tributary to San Timoteo Creek were not modeled as part of the Master Plan.

2.2 Hydraulic Analyses

The proposed improvements follow the CSDP#4 storm drain facility naming convention. The County referred to each system with a "project" number. This convention was used in this study.

Three different methods for hydraulic calculations were used to design the proposed system depending on the size and location of the facilities. For minor, or local systems, and street sections, normal depth calculations were performed using the Flowmaster (Bentley) computer program. The Los Angeles County's Water Surface Pressure Gradient (WSPGW) program was used for evaluating proposed pipe sizes for main storm drains over 36-inches in diameter. WSPGW is a steady state hydraulic model that uses Bernoulli's Equation (Energy Equation) for conduit calculations, and the Pressure/Momentum equation for junctions.

The downtown area, in addition to a portion of Zanja (upstream of the I-10), was modeled and sized using XP Software's XP-SWMM, which is an improved version of the U.S. EPA's Storm Water Management Model (SWMM). XP-SWMM is a dynamic wave model that solves the full St. Venant Equations. Dynamic modeling allows the effects of storage and backwater in conduits and floodplains and the timing of the hydrographs to yield a true representation of the hydraulic conditions. XP-SWMM can model the surface in 2-dimensions, while linking to the subsurface infrastructure, or storm drain system. The result is a comprehensive model that can communicate between the surface and subsurface facilities throughout the modeled design storm duration.

Hydraulic analyses were completed for both existing and proposed conditions for various design storm events. Existing condition analyses were performed to identify the capacity of a given drainage reach or system. This was completed by evaluating the capacity of the street sections, above the storm drain in addition to the storm drain capacity. Street capacities were evaluated by an Excel spreadsheet entitled StreetFlowCalcs+Existing.xlsx which considered pipe and roadway capacities to ultimately identify the level-of-protection necessary for each system. FlowMaster computations to model the hydraulic capacity of roadway sections were incorporated into the Excel spreadsheet. Depending on the size of the laterals or main storm drain lines, the sizes were calculated based on either normal depth or using a combination of energy equation and pressure and momentum.

For existing small open channels, a capacity analysis was performed using FlowMaster. If the facility failed, the proposed new facility was replaced with a reinforced concrete pipe (RCP). This was done for cost purposes. When these facilities are designed and built in the future, alternative conduits will be evaluated during the final design process.

Downtown Area (9th Street – Texas Street)

The downtown area required the use of a more advanced hydraulic model due to the large undersized regional drainage facilities tributary to it. This excess runoff requires an advanced surface model to identify flow quantity and direction as it moves through the downtown area. The City's plans to construct a future "diversion storm drain", in addition to the proposed Opal Basin, provided the basis to estimate their cumulative impacts on the current flood hazard within the downtown area. Traditional hydraulic modeling techniques can not accurately identify these facility impacts on the area. Using the advanced modeling techniques, hydraulic analyses were completed for both existing and proposed conditions using a linked 2-dimensional surface model, and 1-dimensional subsurface model (1D/2D) in XP-SWMM. The existing City storm drains were added to a 3-dimensional surface terrain model to understand the level of flooding, and to create the foundation for identifying appropriate future master planned facilities. Flows, or hydrographs, were added along the Zanja (near the I-10 underpass), Reservoir Canyon storm drain, Church Street storm drain, and near North University Street.

The main focus of this model is the Redlands Boulevard storm drain. All main lateral connections between 9^{th} St. and Texas St. were modeled to identify their performance.

Regional Backbone Facility

Several studies have been completed to identify and alleviate the current flooding conditions in the downtown area. The 1986 U.S Army Corps (Corps) of Engineer's study provided the most detailed evaluation of multiple alternatives. At the time, the Corps used the steady-state flow model HEC-2 to evaluate the floodplain impacts of each alternative. Although the study did not provide technical calculations, alternatives included diverting flows from Zanja to Texas Street to increasing the capacity of the existing Redlands Boulevard storm drain. Their recommended alternative was the diversion structure. Even with this alternative, the Corps recognized that it was pointed out with the Zanja flows diverted, the 100-year flows from the Reservoir Canyon storm drain would still cause up to 1.5' of flooding in the downtown area.

RBF Consulting prepared several alternatives using the much more advanced hydraulic model, XP-SWMM, to identify the best regional drainage solution through the downtown area based on the SBCFCD revised CSDP#4 100-year hydrology. These alternatives included the planned future planned "diversion structure" and replacing the Redlands Boulevard storm drain. Alternatives were performed and compared to existing conditions to understand the levels of protection each alternative provided.

Section 3.3 discusses the model calculations and results.

2.2.1 Existing Conditions

The existing condition calculations were performed for the downtown area to identify existing street conveyance and storm drain deficiencies. Since the City of Redlands does not have published design criteria, the SBCFCD's criteria recommended in the CDSP#4 were used. The following sub-sections describe the methods used to analyze the existing condition hydraulics.

2.2.1.1 Downstream Water Surface Control Elevations

For the facilities that drain directly into large or regional facilities, criteria had to be estimated for the downstream tail water conditions. The depth of flow estimated in these large facilities greatly impact the hydraulic performances of the local facilities connecting to them.

Four different methods were used to determine the downstream water surface control elevation for the existing conditions hydraulic analyses:

1. Hydraulic grade lines from the As-built plans provided by the City of Redlands.
2. In areas where storm drains were tributary to other storm drains, water surface elevations were taken from the downstream models.
3. If no other information was available, the water surface elevation in large open channels was assumed to be three feet (3-ft) below the ground surface elevation at top of channel. The criteria were selected based on the County's "Earthen Channel Design Requirements (S.P. 100) for velocities over 8 feet per second. Since the MPD does not include bulked flows, this portion of the criteria was not used.

The majority of the models did not have as-built plans with HGLs, so methods 2 and 3 were predominantly used.

Table 2.1 below provides a summary of the street protection level discussed in section 2.1.1.

Table 2-1: Design Protection Levels for Streets

Type of Street	Storm Frequency	Maximum Allowable Flooding
Local	10-yr & 25-yr sump condition	Top of Curb
	100-yr	At adjacent pad elevation
Arterial Highway	10-yr & 25-yr sump condition	17 feet flooded width within road (or one dry lane in each direction)
	25-yr	Top of Curb
	100-yr	At lowest point in adjacent pad elevation

Each street type was designed based on its size and grade. Local streets are smaller two-lane facilities typically located within the residential and rural areas. Arterial highways consists of the larger multiple lane facilities that are typically located in high volume traffic areas.

The grade of the street can be described as either continuous or sump conditions. Continuous grades are street sections that do not have a low point, but rather slope in a continuous direction. Catch basins are typically designed in these facilities based on the allowable flow “spread” within the street. Sump locations within a street are low points, where excess runoff would generally pond. These locations typically create most of the local flooding during storm events as they are designed to capture the overflow runoff from upstream continuous grade inlets in addition to their respective tributary drainage area. Larger catch basin inlets are generally located at these locations.

The street capacity calculations were completed utilizing an excel spreadsheet developed for this study. Each drainage area was analyzed using the flow rates from the respective existing condition hydrology minus the existing storm drain capacities. The flow above the storm drain was assumed to be in the streets and normal depth was used to determine flow depths. If any of the above design protection levels were exceeded, the existing system was classified as deficient.

2.2.2 <u>Proposed Conditions</u>

The following sub-sections discuss the Proposed Condition Hydraulic analyses and the methods used. For subsurface storm drain infrastructure below streets, a proposed hydraulic grade line (HGL) of two feet (2-ft) below street surface was assumed. This would allow sufficient inlet conveyance capacity along the street sections to capture appropriate flows (as in Table 2.1).

2.2.2.1 Normal Depth Storm Drain Sizing (Local Storm Drains)

In order to determine the approximate required pipe size for the deficiency removals in areas outside major or main storm drain areas, an excel spreadsheet specifically developed for this study was used.

Normal depth was used to perform street flooded width analyses and calculate the proposed storm drain sizes. Each system was sized for the 10-, 25-, and 100-year storm events and then upsized if any of the Design Protection levels were still exceeded. Since normal depth calculations do not take into account downstream backwater conditions, the calculated pipe sizes were rounded up to the nearest 6 inches. The detailed procedure taken to complete this analysis, including discussions of how the calculation spreadsheet was constructed and what each of columns represent is included in Appendix B.

In cases where proposed systems discharge to existing regional facilities, a separate sensitivity analysis was performed on the facility size (determined based on normal depth). This was performed using the WSPGW hydraulic model, with the downstream control set based on the criteria in Section 2.2.1.1. The proposed facility size was upsized where necessary as determined by the WSPGW hydraulic calculation. A Storm Drain Facility ID Map is included as Exhibit 3.

The required sizes are discussed in detail in each drainage area (Sections 3).

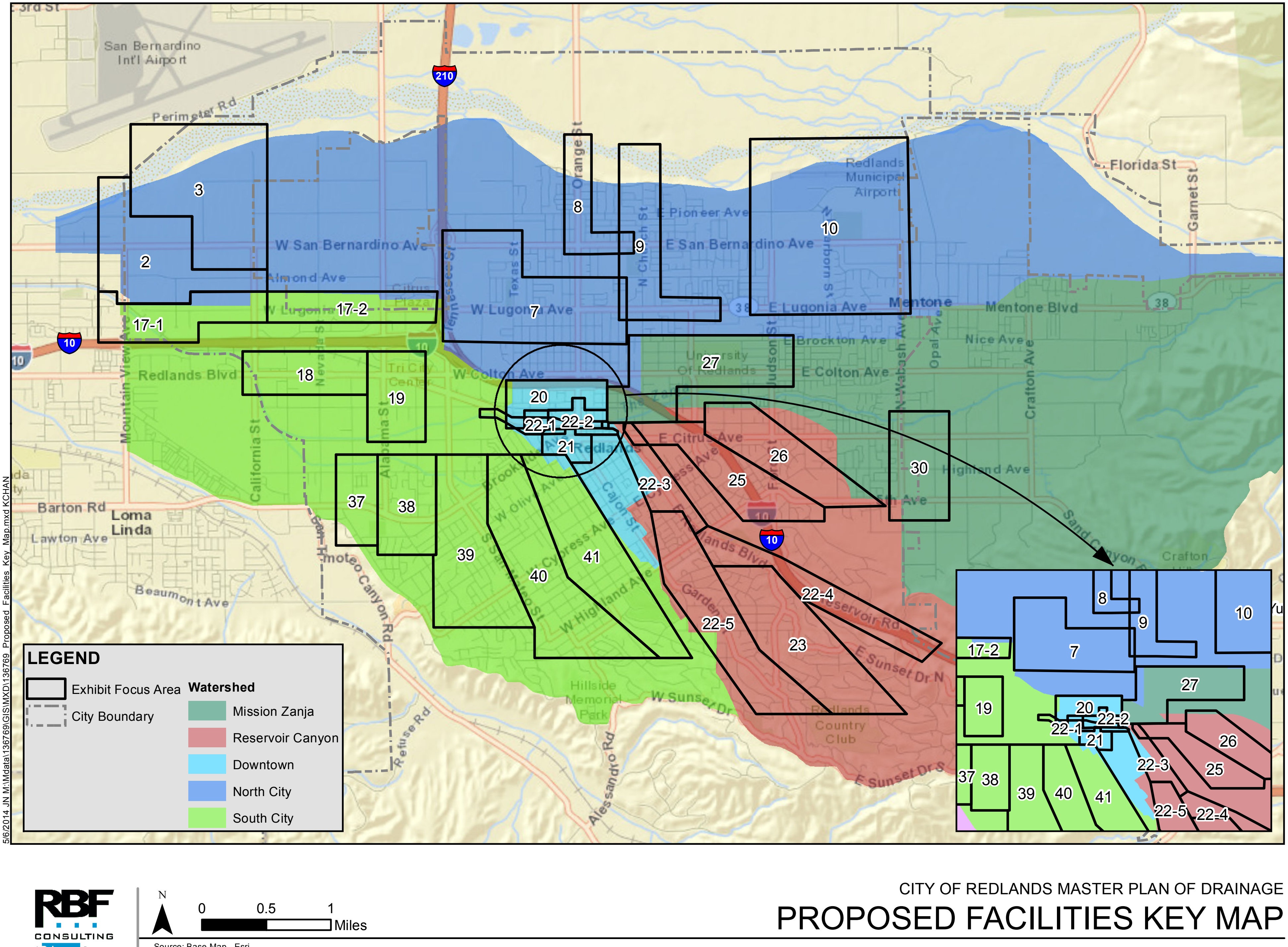
2.2.2.2 Main Lateral Storm Drain Sizing

For most subsurface storm drain systems 36-inch diameter and larger, WSPGW was used to analyze the systems. WSPGW models the impact of downstream tailwater conditions, and thus provides more accurate results than normal depth calculations.

For the downtown area of the MPD, XP-SWMM was used to size the proposed drainage facilities. As part of the regional model to evaluate Zanja and Reservoir Canyon Channel, the downtown local facilities that were connected to the Redlands Boulevard storm drain. Since these laterals were already a part of the regional model, it was more beneficial to size them in XP-SWMM.

2.2.2.3 Facility Naming Convention

The storm drain facilities were identified based on the CSDP#4 naming convention. For areas where new storm drains were recommended, the naming convention was sequentially increased for that particular storm drain or “project” as they are referred to in the CSDP#4. For the facilities key map, refer to Figure 3-1.



5/6/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities_Key_Map.mxd KCHAN

RBF CONSULTING
A Baker Company

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

PROPOSED FACILITIES KEY MAP

Figure 2-1

2.3 Facility Priority Evaluations

A priority ranking has been developed based on the projects of greatest importance. A process has been prepared to determine which projects should be constructed first when funding becomes available. The three priorities are summarized below: Refer to Exhibit 4 for a map containing priority storm drains.

- **Priority 1a (*highest priority*)**
  - *Local Streets* – Existing streets and storm drain systems where flood depth is above the right-of-way in the 10-year storm event.
  - *Arterial Streets* - Existing streets and storm drain systems where flood depth is above the right-of-way in the 25-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 10-year flood protection AND overflows impact multiple adjacent local facilities.
- **Priority 1b**
  - *Local Streets* **–** Existing streets and storm drain systems where flood depth is above top of the curb in 10-year storm event.
  - *Arterial Streets* **-** Existing streets and storm drain systems where flood depth is above top of curb in the 25-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 25-year flood protection AND overflows impact multiple adjacent local facilities.
- **Priority 2**
  - *Arterial Streets* **-** Existing streets and storm drain systems where flooded width is greater than 17 feet in the 10-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 100-year flood protection AND overflows impact multiple adjacent local facilities.
- **Priority 3**
  - *Local Streets* **–** Existing streets and storm drain systems where flood depth is above the right-of-way in the 100-year storm event.
  - *Arterial Streets* **-** Existing streets and storm drain systems where flood depth is above the right-of-way in the 100-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 100-year flood protection AND overflows impact multiple adjacent local facilities.

2.4 Cost Estimates

Cost estimates were created for the proposed condition of new or replacement storm drain systems. The unit prices were developed in cooperation with the City and current market values.

The calculated system costs estimates include costs for engineering, construction, SWPPP, surveying, construction management and contingencies. Any new storm drain construction within the City most likely will require utility relocation. This can be very costly especially considering the downtown area is highly urbanized and with infrastructure dating back over 100 years. The quantity and complexity of utility relocation is unknown and requires detailed site specific subsurface investigations.

Pipe costs are per linear foot and included costs for excavation, shoring, bedding, backfill, compaction, removal of excess material, and trench resurfacing.

Due to the fact that construction will take place over a number of years, the total cost of master plan implementation will vary from the numbers provided in this study. It is recommended that any future implementation plans take into account future construction unit costs prior to creating a funding program for the Master Plan of Drainage. The Engineering Construction Cost Index is 9750 as of this report.

3 Drainage Area Results

3.1 Mission Zanja Drainage Area

3.1.1 Hydrologic Analysis

The hydrology analysis was achieved using the County's CSDP#4 and the Rational Method model for each storm event analyzed. The County models were created for the AMC II 10-, 25-, and 100-year storm events. The analysis was conducted per the SBCFCD Hydrology Manual and methods discussed in Section 2. A cursory review of the County models was performed to verify parameter accuracy. In some cases, drainage areas had to be modified to produce peak flows at particular locations for the hydraulic modeling. Upstream reaches of the Zanja were recalculated to use a more realistic Manning's "n" value in the models. The County assumed future built-out conditions of a concrete channel (Manning's value of 0.015), which will not likely happen due to the Zanja's historical value. Consequently, the Manning's value was raised to 0.035 to indicate natural conditions and overland flow characteristics.

Hydrology node numbering conventions are consistent with those found in the CSDP#4 Report. Regional hydrology model results of Area 1 can be found in Appendix A. Table 3-1 below provides a summary of the hydrology analyses results.

For the XP-SWMM analysis, unit hydrographs were created for the drainage area. XP-SWMM is an unsteady flow regime model that requires hydrograph input, rather than Rational Method peak flow.

Table 3-1: Mission Zanja Drainage Area Hydrology Summary (AMC II)

Node	Location	Drainage Area (ac)	100-Year Flow (cfs)
Mission Zanja			
20353/76	Opal Basin	4068.9	3161.9
20454	I-10 Freeway	5435.8	3923.8
20539	9th Street	5454.9	3923.8
20955	Conf. with Reservoir Canyon	10026.4	4124.4
21045	At Texas Street	10518.3	6250.3

3.1.2 Hydraulic Analysis

This area consists of mostly natural channel flows through the Zanja until Wabash Avenue, where it transitions to an earthen trapezoidal channel. This engineered channel extends to Lincoln Street, where it transitions back to a natural channel until the I-10 underpass. Several small culvert roadway crossing exist between Lincoln Street and the I-10. From the I-10, the Zanja is conveyed in an earthen trapezoidal channel until 9th Street, where it is picked up in a reinforced concrete box culvert. Due to the historical value of the Zanja, the focus was not to "engineer" a more efficient channel section through the reach, but rather to reduce the peak flow via attenuation upstream in the proposed Opal Basin.

The 9th Street culvert is a location with insufficient capacity for large storm events. Even with the Opal Basin implemented, this location has been identified as a restriction in the conveyance. 9th Street is the location planned for the downtown diversion structure. The proposed model will evaluate multiple storm drain sizes and shapes to identify the most hydraulically efficient section.

From Wabash Avenue to 9th Street, this area was hydraulically modeled using XP-SWMM, linking a two dimensional surface model with XP2D a fully dynamic 1-dimensional subsurface model. The program is capable of performing the advanced hydraulic calculations necessary to model the flow "split" of the Zanja at 9th Street, as well as, to model the amount and direction of any surface flows not captured by the dual system. No hydraulic models or improvements were calculated upstream of Wabash Avenue.

The existing 5-ft (h) x 8-ft (w) RCB inlet at 9th Street has an approximate capacity of 540 cubic feet per second (cfs) before it overtops. The 100-year tributary peak flow at that point in the Zanja is approximately 4,200 cfs. The large variance between the design flow and the system capacity indicate that additional improvements to the inlet configuration will be required. This area was also identified in the Corps report as a major deficiency. Limitations on this facility's height will cause an issue with capacity, even after improvement.

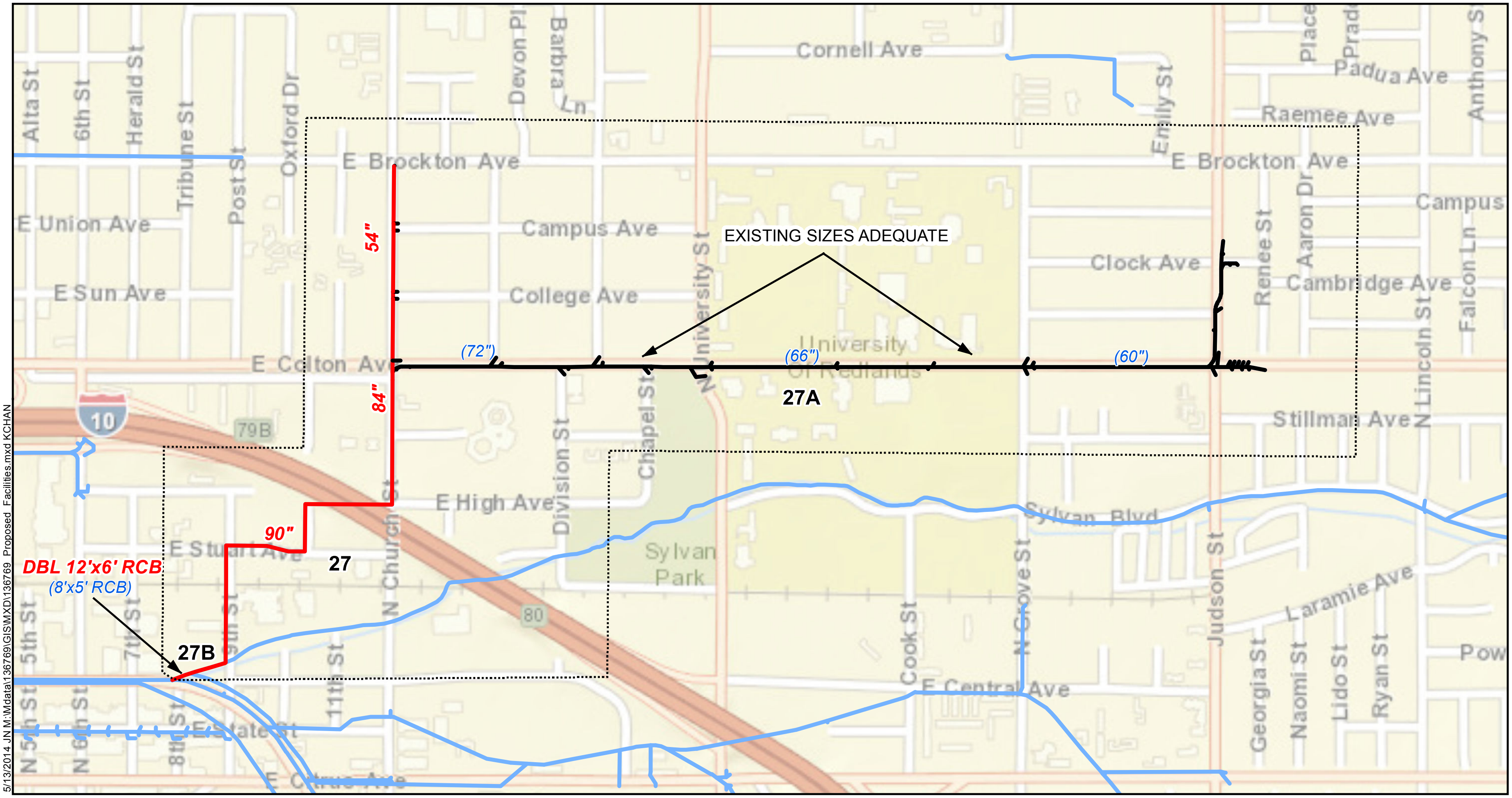
The proposed condition XP-SWMM analysis included the proposed Opal Basin, an improved inlet at the existing 9th Street, and an optimized system downstream of 9th Street. For details on these facilities, refer to Section 3.3 Downtown Area results. For a detailed XP-SWMM input parameter discussion, refer to Appendix B.

3.1.3 Proposed Improvements

Table 3-5 is a summary of the proposed systems for this area. See Appendix B for the Proposed Conditions Analyses. In this reach, the only regional improvement proposed is the Opal Basin. Minor improvements of low water crossings are not included in this analysis, since they are currently designed as low-flow crossings. Improvements to the Zanja 9th Street inlet and the diversion structure are part of the Downtown Area improvements, but needed to be modeled in the Zanja Area model to create a seamless model connection.

Table 3-2: Mission Zanja Drainage Area Proposed Improvements

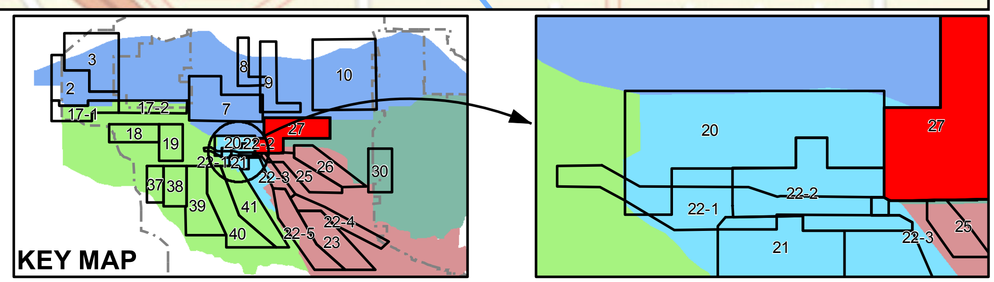
System #	Existing Facility	Proposed Facility	
		Replacement Conduit	
	Conduit Size	Diameter (inches)	Length (ft)
27	Unknown	54	1,315
	Unknown	84	1,120
	Unknown	90	2,923
27-B	8'x5' RCB	(2) 12'x6'RCB	385



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- 2A Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING A Baker Company

N

0 900 1,800 Feet

Source: Base Map - Esri

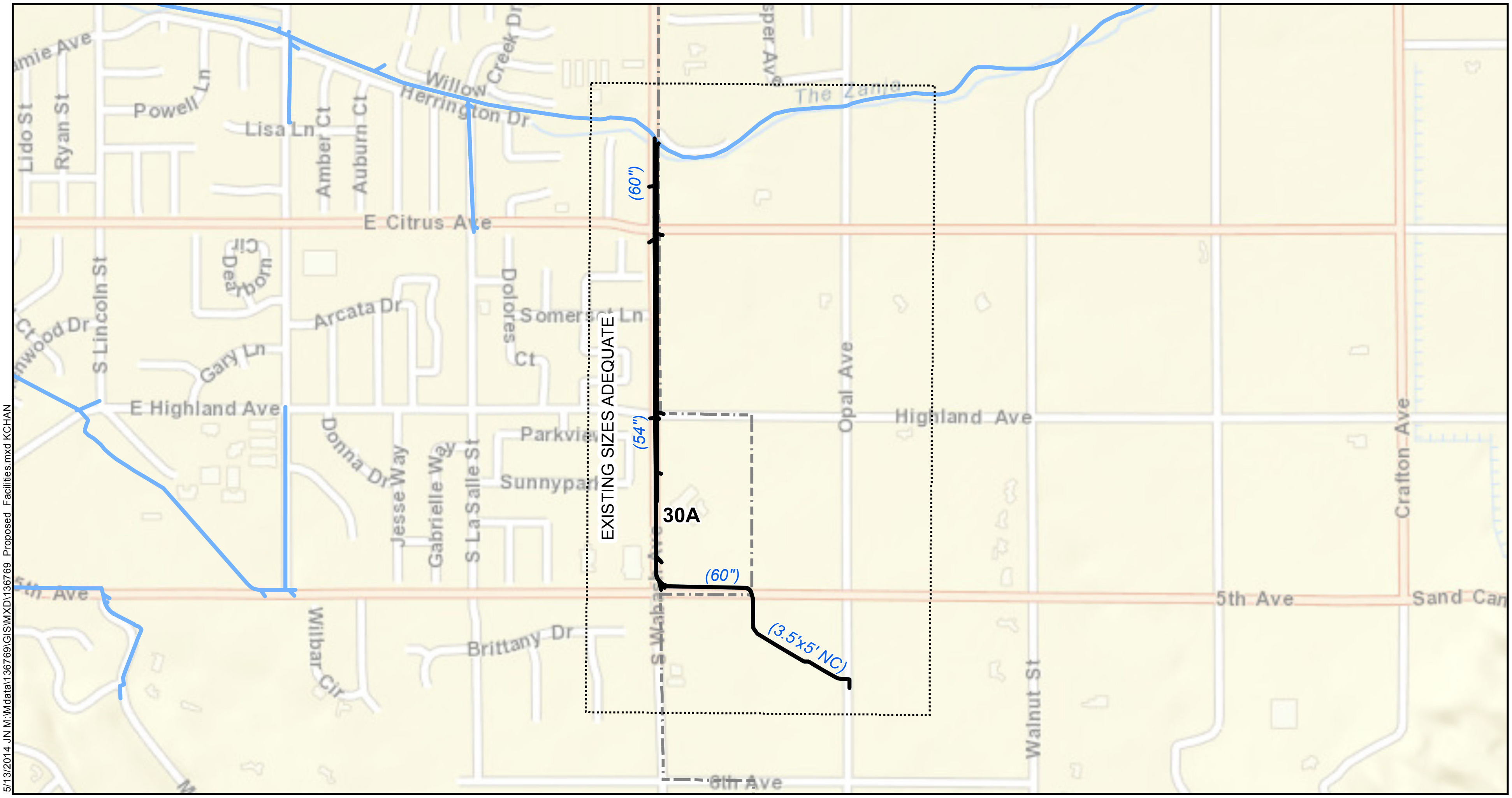
CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: ZANJA CHANNEL

MAIN STORM DRAIN FACILITIES - PROJECT AREA 27

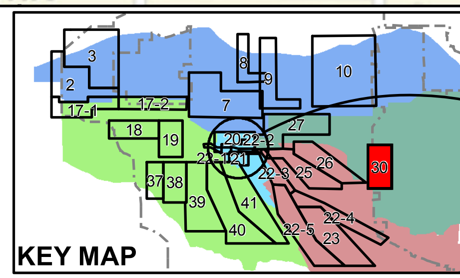
FIGURE 3-1A

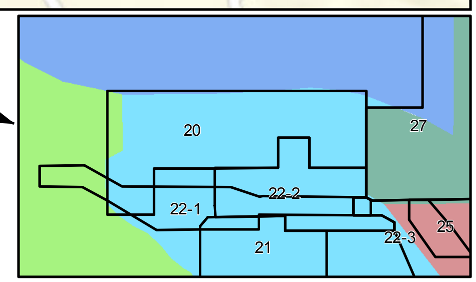
5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN



LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City





RBF CONSULTING
A Baker Company

0 1,000 2,000 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: ZANJA CHANNEL

MAIN STORM DRAIN FACILITIES - PROJECT AREA 30

FIGURE 3-1B

3.1.4 Cost Estimates

For the system, RBF has provided a recommendation for replacing the storm drain facilities. Table 3-3 gives a summary of the construction cost estimates and the recommended system within the Zanja Drainage Area. See Appendix C for detailed cost estimates.

Table 3-3: Mission Zanja Drainage Area Cost Estimate Summary

System No.	Recommended System Diameter (inches)	Total Project Cost (2014 $)
27	54	$454,000
	84	$631,000
	90	$1,731,000
27-B	(2) 8'w x 6'h RCB	$924,000
Opal Basin	Basin	$15,000,000
	Total System Cost	**$18,740,000**

3.2 Reservoir Canyon Drainage Area

3.2.1 Hydrologic Analysis

The hydrology analysis was achieved using the County's CSDP#4 and the Rational Method model for each storm event analyzed. The analysis was conducted per the SBCFCD Hydrology Manual and methods discussed in Section 2. A cursory review of the County models was performed to verify accuracy. In some cases, drainage areas had to be modified to produce peak flows at particular locations for the hydraulic modeling.

Hydrology node numbering conventions are consistent with those found in the CSDP#4 Report. Regional hydrology model results of can be found in Appendix A. See Figure 1-3 for the Reservoir Canyon Watershed Map. Table 3-4 below provides a summary of the hydrology analyses results.

For the XP-SWMM analysis, unit hydrographs were created for the drainage area. XP-SWMM is an unsteady flow regime model that requires hydrograph input, rather than Rational Method peak flow. Some portions of this area were modeled in XP-SWMM as an input to the Downtown Area XP-SWMM model.

Table 3-4: Reservoir Canyon Drainage Area Hydrology Summary (AMCII)

Node	Location	Drainage Area (ac)	100-Year Flow (cfs)
Reservoir Canyon			
20764		1696.4	2073.7
20829	Palm Ave.	2763.5	3060.2
20852	Home Pl.	2992.9	3209.4
20940	State St.	3993.8	4007.8
20955	Conf. with Mission Zanja	3993.8	4007.8

3.2.2 Hydraulic Analysis

The area consists of both open channel and subsurface storm drain facilities. The drainage facilities are generally tributary to the Reservoir Canyon storm drain upstream of the confluence with the Zanja at Redlands Boulevard near 9th Street. The watershed includes drainage facilities east of the I-10.

Most of the Reservoir Canyon storm drain downstream of Cypress Avenue was analyzed using XP-SWMM. This was the case to identify the inflow parameters for the Downtown Area model. The drainage facilities upstream of this crossing were performed using WSPGW.

The Reservoir Canyon Storm drain was constructed 1985. The capacity of this facility is larger upstream of Cypress Avenue due to the steep slope of the facility. When the facility joins the Redlands Boulevard storm drain, and confluences with the Zanja storm drain, the system is over capacity. An estimated 100-year peak flow of 3,250 cfs is tributary to this confluence from Reservoir Canyon. Even with the implementation of the Opal Basin and the previously planned regional Downtown improvements, these peak flows from this area exceed the capacity of the existing Redlands Boulevard storm drain.

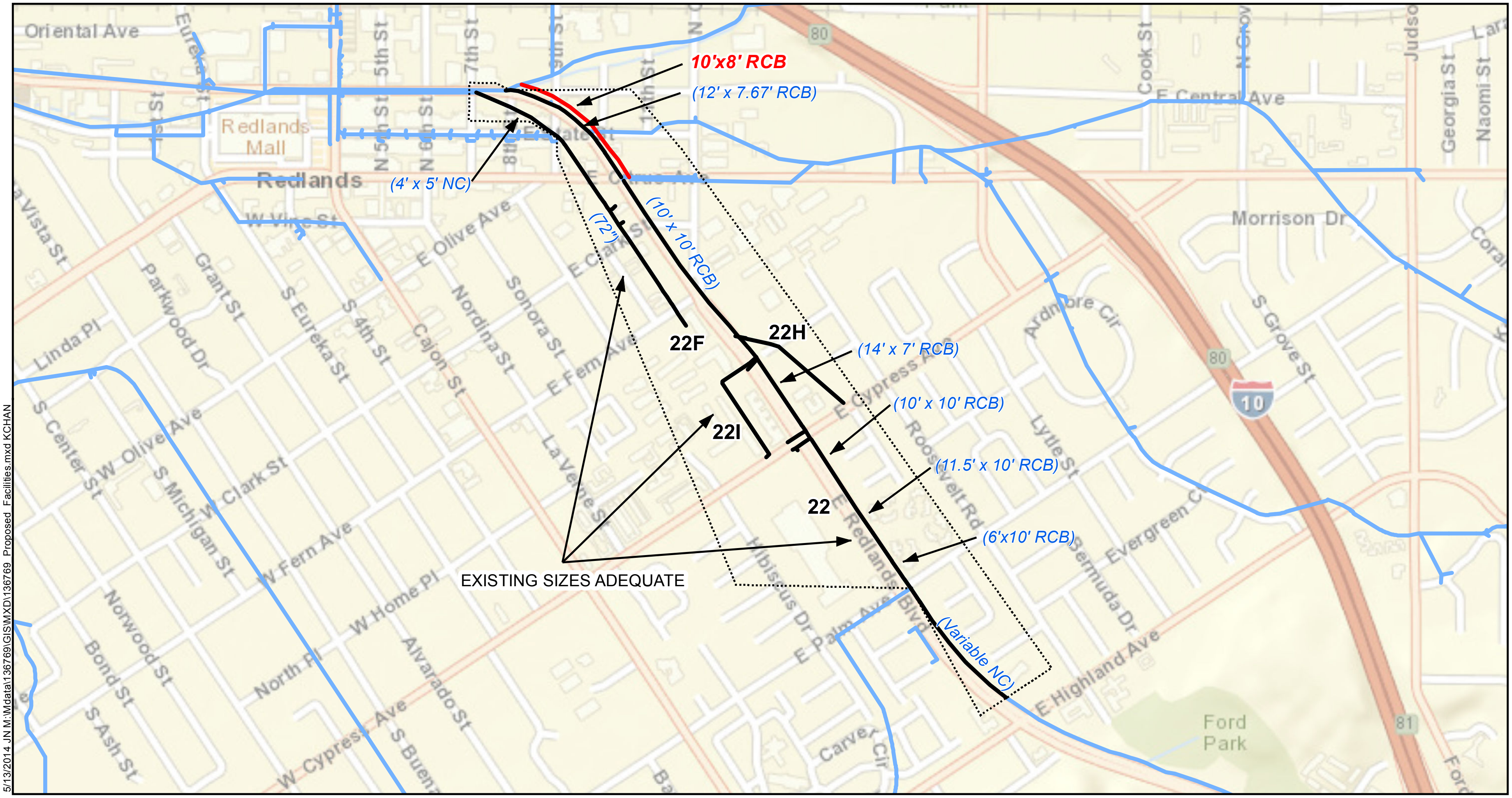
Previous studies have shown that no feasible flood attenuation/retention location can be identified within this watershed. As a result, storm drain facility improvements were deemed to be the most feasible alternative.

3.2.3 Proposed Improvements

Table 3-5 is a summary of the calculated proposed systems for each facility in this area. See Appendix B for the Proposed Conditions Street Flow Analyses.

Table 3-5: Reservoir Canyon Drainage Area Proposed Improvements

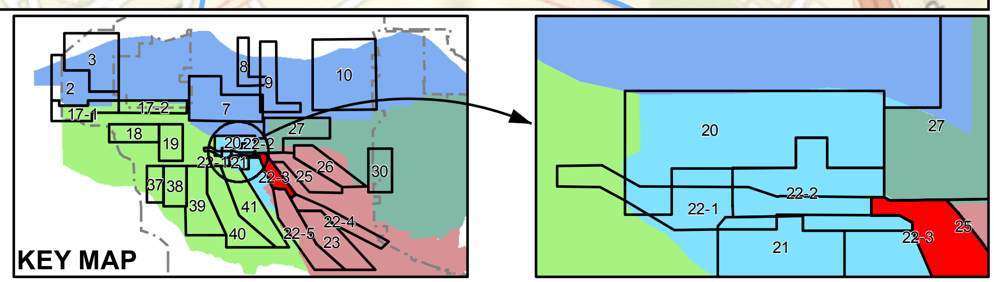
System #	Existing Facility	Proposed Facility	
		Replacement Conduit	
	Conduit Size	Diameter (in)	Length (ft)
22	N/A	RCB	1,019
22-G	N/A	RCB	1,174
22-J	51	78	2,911
	RCB	RCB	6,469
25A	RCB	RCB	317
	Unknown	72	7,014
	Unknown	78	228
26A	Unknown	48	1,375



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

36"	Proposed Main Line Sizes
(36")	Existing Main Line Sizes
RCC	Rectangular Concrete Channel (W'xH')
NC	Natural Channel (W'xH')
2A	Storm Drain Facility ID
	Proposed Storm Drain Facility
	Existing Storm Drain Facility
	Storm Drain Facilities Shown Elsewhere
	City Boundary
	Exhibit Focus Area
	Mission Zanja
	Reservoir Canyon
	Downtown
	North City
	South City



RBF CONSULTING A Baker Company

N

0 1,050 2,100 Feet

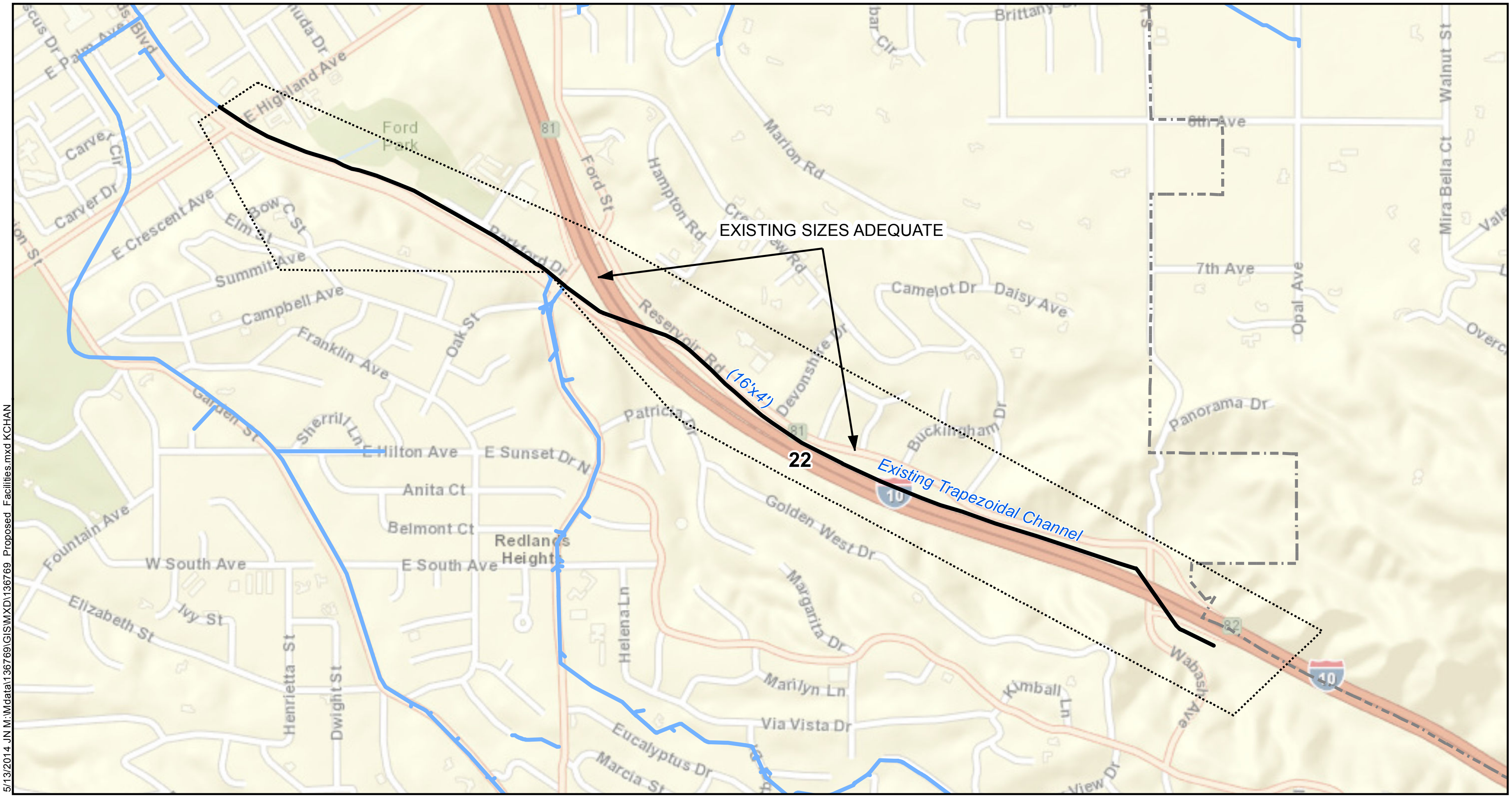
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: RESEVOIR CANYON

MAIN STORM DRAIN FACILITIES - PROJECT AREA 22-3

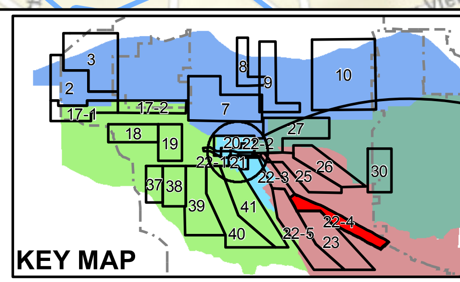
FIGURE 3-2A

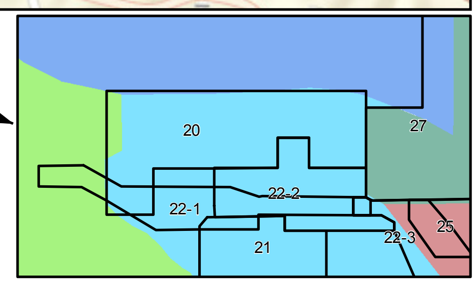


5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- 2A Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City





RBF CONSULTING A Baker Company

N

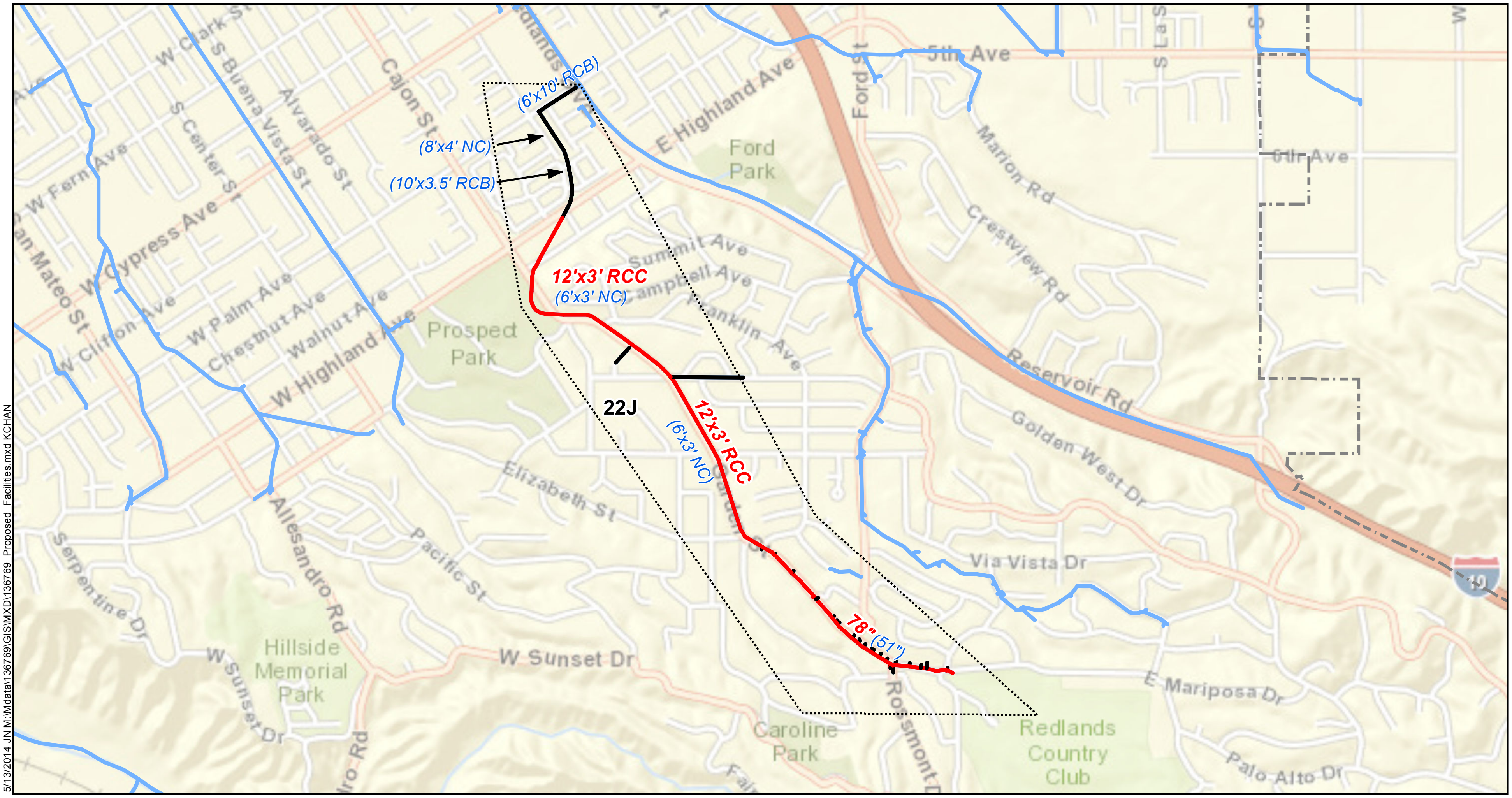
0 1,250 2,500 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: RESEVOIR CANYON

MAIN STORM DRAIN FACILITIES - PROJECT AREA 22-4

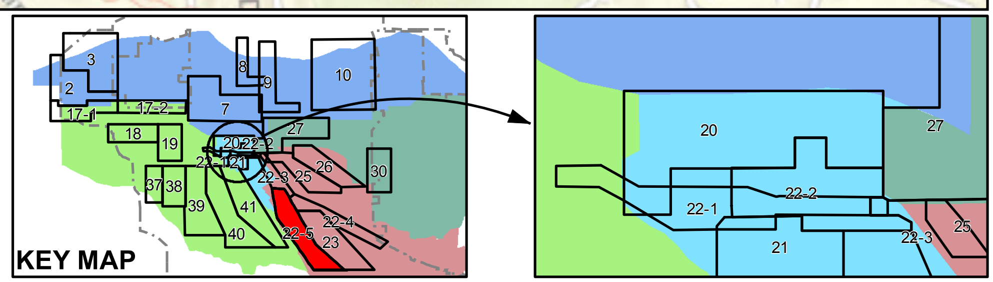
FIGURE 3-2B



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING
A Baker Company

N

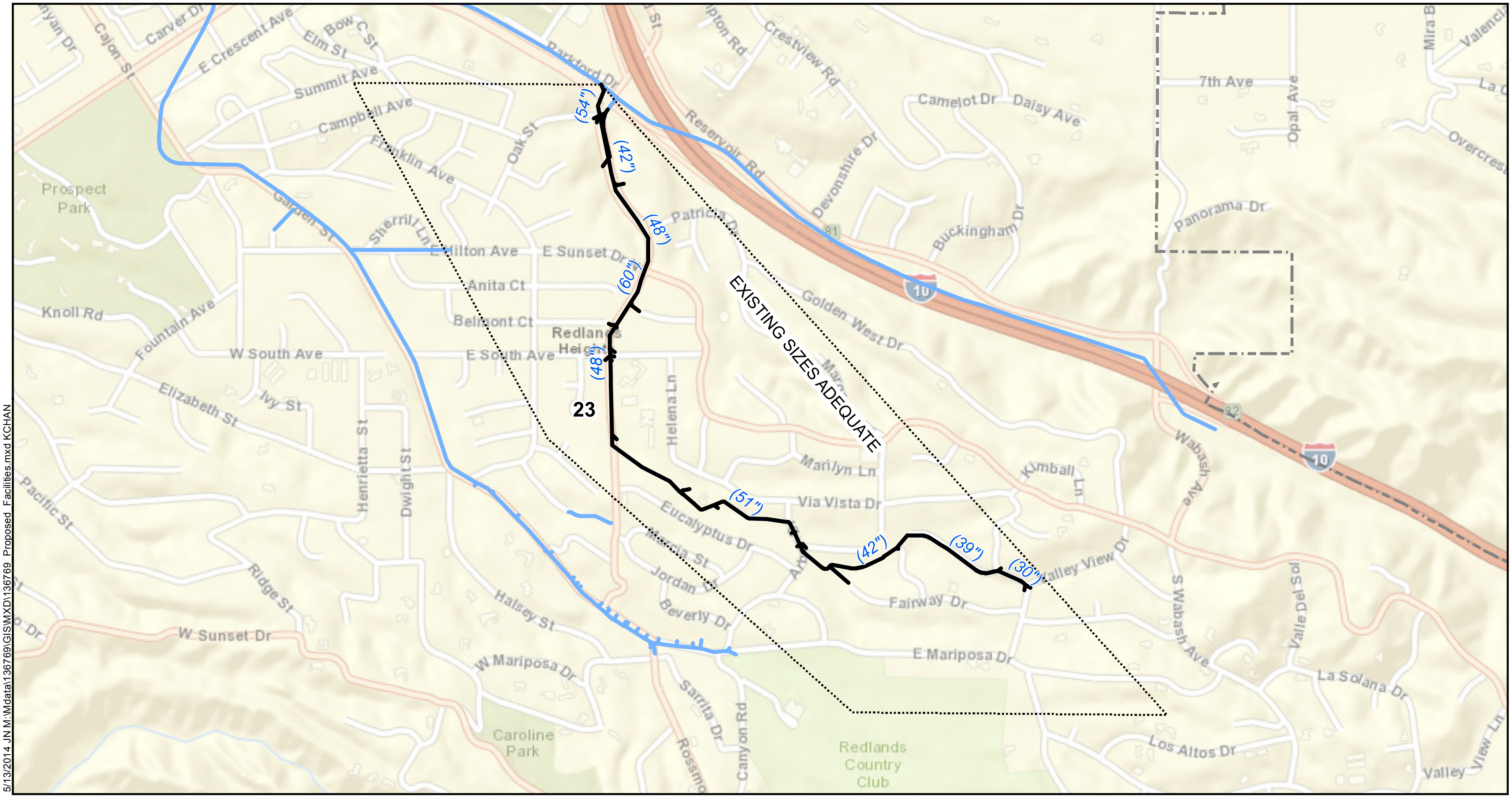
0 1,875 3,750 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: RESEVOIR CANYON

MAIN STORM DRAIN FACILITIES - PROJECT AREA 22-5

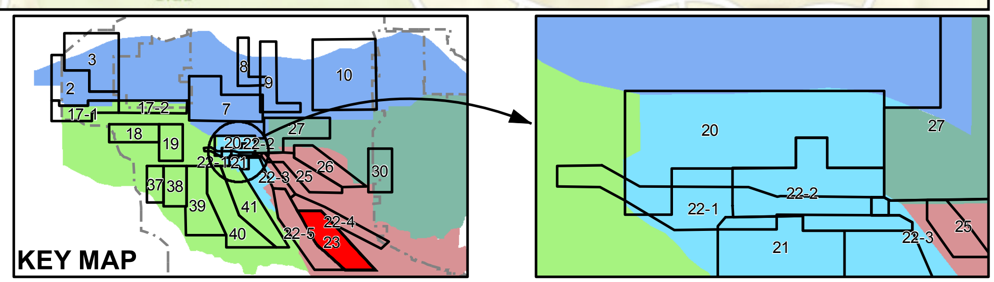
FIGURE 3-2C



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- ***36"*** Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING A Baker Company

N

0 1,375 2,750 Feet

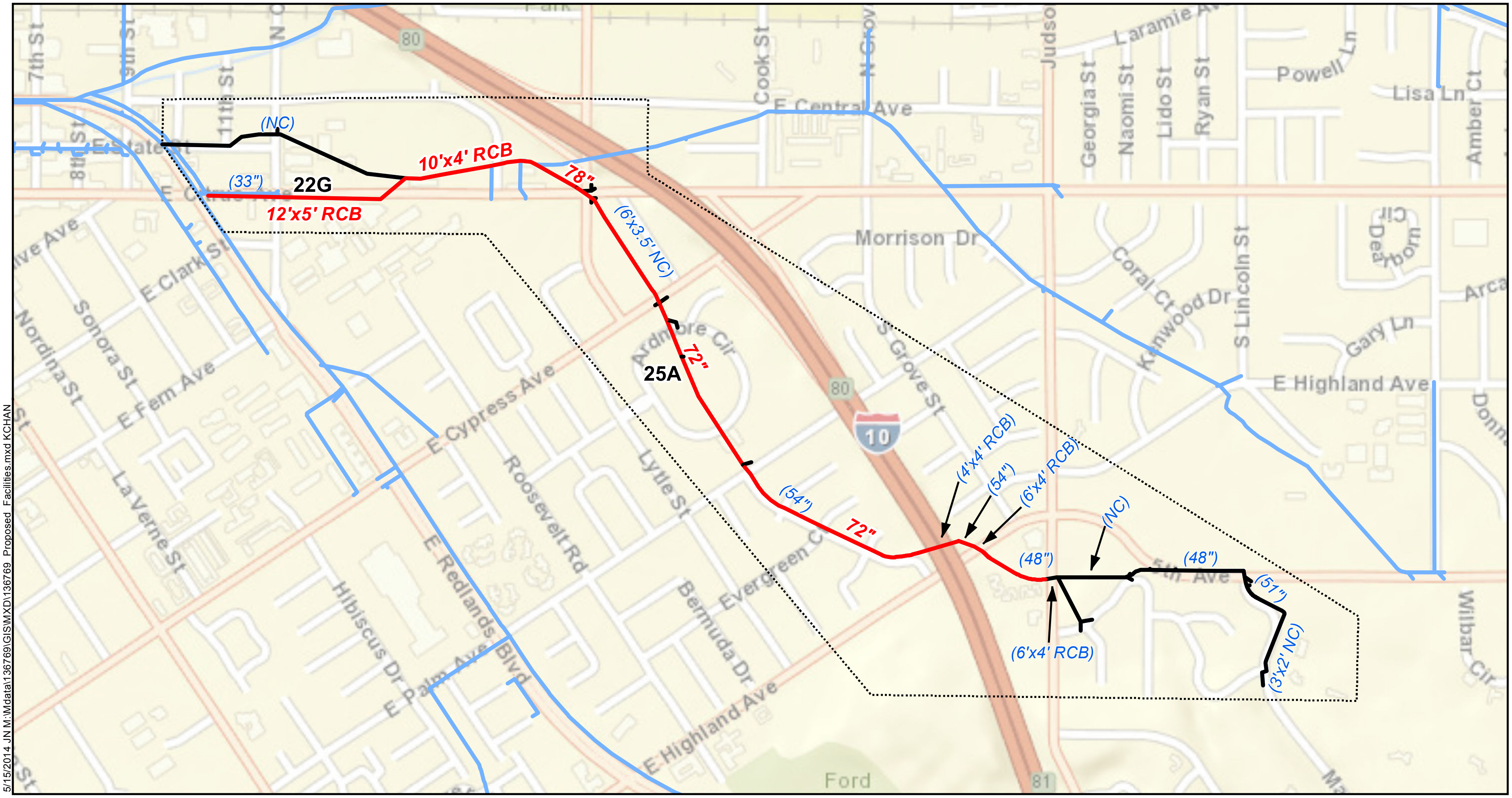
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: RESEVOIR CANYON

MAIN STORM DRAIN FACILITIES - PROJECT AREA 23

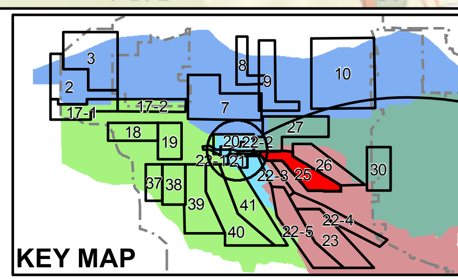
FIGURE 3-2D

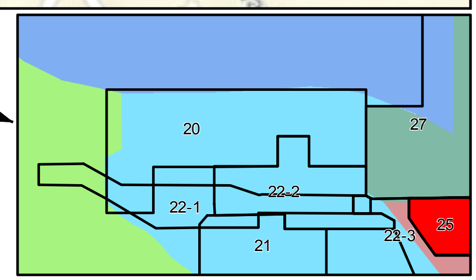


5/15/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City





RBF CONSULTING
A Baker Company

N

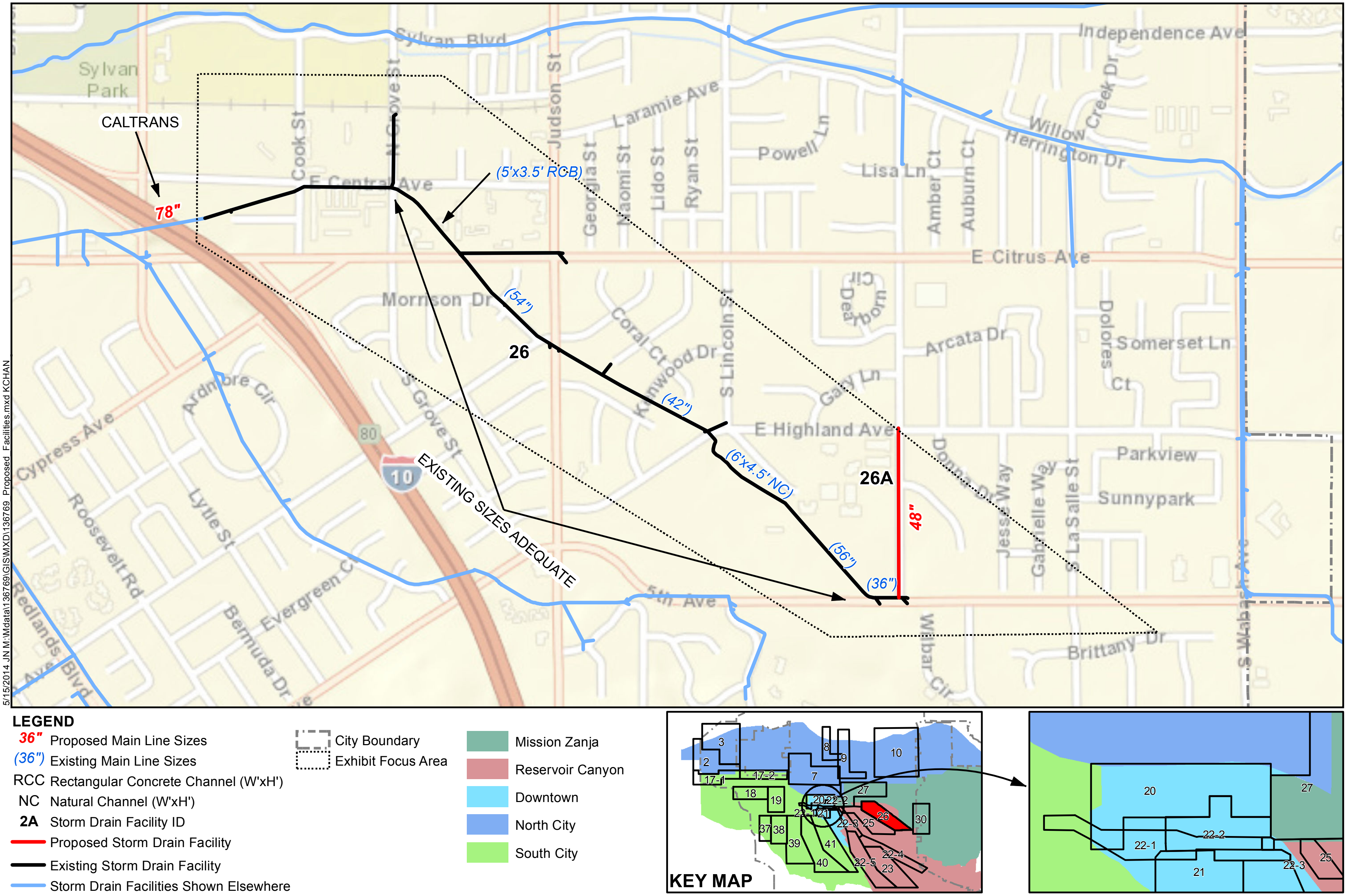
0 950 1,900 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: RESEVOIR CANYON

MAIN STORM DRAIN FACILITIES - PROJECT AREA 25

FIGURE 3-2E



LEGEND

- *36"* Proposed Main Line Sizes
- (36") Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- 2A Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City

5/15/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

RBF CONSULTING A Baker Company

N

0 950 1,900 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: RESEVOIR CANYON

MAIN STORM DRAIN FACILITIES - PROJECT AREA 26

FIGURE 3-2F

3.2.4 Cost Estimates

For the system, RBF has provided a recommendation for replacing the storm drain facilities. Table 3-6 gives a summary of the construction cost estimates and the recommended system within the Reservoir Canyon drainage area. See Appendix C for detailed cost estimates.

Table 3-6: Reservoir Canyon Drainage Area Cost Estimate Summary

System No.	Recommended System Diameter (inches)	Total Project Cost (2014 $)
22	10'w x 8'h RCB	$1,223,000
22-G	12'w x 5'h RCB	$1,409,000
22-J	78	$1,506,000
	12'w x 3'h RCC	$7,763,000
25A	(2) 10'w X4'h RCB	$761,000
	72	$3,267,000
	78	$118,000
26A	48	$459,000
	Total System Cost	**$16,505,000**

ENR Construction Cost Index = 9750 (April 2014)

3.3 Downtown Drainage Area

3.3.1 Hydrologic Analysis

The hydrology analysis was achieved using the County's CSDP#4 and the Rational Method model for each storm event analyzed. The analysis was conducted per the SBCFCD Hydrology Manual and methods discussed in Section 2. A cursory review of the County models was performed to verify accuracy. In some cases, drainage areas had to be modified to produce peak flows at particular locations for the hydraulic modeling. Some of the local sub-drainage areas found within the Downtown Area needed to be re-evaluated when comparing as-built plans to the County hydrologic boundaries.

Hydrology node numbering conventions are consistent with those found in the CSDP#4 report. Regional hydrology model results of this area can be found in Appendix A. See Figure 1-3 for the Downtown Area Watershed Map. Table 3-7 below provides a summary of the hydrology analyses results.

Table 3-7: Downtown Drainage Area Hydrology Summary (AMCII)

Node	Location	Drainage Area (ac)	100-Year Flow (cfs)
Downtown			
20968	3rd Street	12.9	43.1
21093	Eureka St	7.4	24.8
21045	Texas SD	25.6	70.8

3.3.2 Hydraulic Analysis

The Downtown Area contains the majority of storm drainage infrastructure within the City boundaries. The facilities consist of both open channels and subsurface storm drains. The area facilities generally drain to the Redlands Avenue storm drain. The watershed is bound by the I-10 freeway to the north and east, and Reservoir Canyon and the South City Areas to the South.

This area was analyzed using XP-SWMM. Inflow hydrographs were developed for the two regional inflows from Zanja and Reservoir Canyon for both proposed (with Opal Basin) and existing conditions. The local drainage tributaries within the downtown area were also calculated as hydrographs inputs for each of the storm drain systems. In the proposed condition model, regional flood control measures were evaluated.

Regional Alternative Analyses

RBF evaluated the City's planned diversion structure, or "bypass" storm drain in conjunction with the proposed Opal Basin to identify where the system was hydraulically efficient or deficient. Based on the results of the advanced model, the system would fail at several locations. Due to the peak flows from the Reservoir Canyon watershed, the existing Redlands Boulevard storm drain exceeded capacity, regardless of how much flow was diverted from the Zanja. If this planned system were to be implemented successfully, the Redlands Boulevard storm drain would also have to be improved.

RBF performed several alternatives and identified two that would reduce the downtown flooding to an acceptable level; 1) Increase Redlands Boulevard storm drain capacity; and 2) Bypassing the entire Zanja around the downtown Redlands Boulevard storm drain. Refer to Figures 3-3 and 3-4. The two regional alternative solutions are described below.

Alternative 1 (Redlands Boulevard Alignment)

- Addition of single-cell culvert next to existing Redlands Boulevard storm drain from Citrus Avenue to downstream of Texas Street.
- Increase capacity of Zanja inlet at 9th Street to the Redlands Boulevard storm drain.
- Improve Oriental storm drain from I-10 to Redlands Boulevard.
- Improve Zanja channel from 9th Street to I-10.

Alternative 2 (Bypass Alignment)

- Redirection of Zanja from 9th Street to downstream of Texas Street (eliminate 9th Street Zanja inlet).
- Construct a diversion pipe in the Reservoir Canyon storm drain from 9th Street/Redlands Boulevard to the bypass structure to alleviate surcharged Redlands Boulevard storm drain.
- Improve Oriental storm drain from I-10 to Redlands Boulevard.
- Improve Zanja channel from 9th Street to I-10.

RBF performed sensitivity analyses for both these alternatives assuming only the large, regional facilities were upsized. This evaluation was performed to identify the approximate sizes needed to convey the large flows in the major facilities. Preliminary costs of these proposed facilities were calculated based on a similar unit price. Another criteria that were reviewed is the constructability of each alternative. Both alternatives have potential issues that could incur more costs. Alternative 1 is located along Redlands Boulevard, which is a main thoroughfare in the City of Redlands. By constructing a large box culvert adjacent to the existing culvert, much (if not all) of the road would need to be temporarily closed. This could cause temporary impacts to the local businesses located along Redlands Boulevard.

Existing utilities along Redlands Boulevard could also pose an issue during construction. Our alternative analyses assumed a RCB of similar height to minimize potential conflicts with utilities running perpendicular, over the box. But for utilities running parallel, relocation may be necessary.

Alternative 2 has several issues that could eliminate it from consideration. Based on the calculated size of the proposed bypass structure needed to convey enough flows to eliminate flooding downtown, the existing easement width is too small. In some locations along the proposed alignment, the easement width ranges from as small as 26 to 30-feet and bound by buildings. The width of the proposed facility is approximately 27-feet wide. For constructing storm drainage systems of this nature, a typical minimum of 10-feet on each side is required. That would indicate that for a few locations along this easement, anything larger that 6 to 10-feet wide is not constructible. If this alternative were to be considered, it would have to be comprised of several small branching bypass structures.

Alternative 1 had a preliminary cost of just over $14,000,000, not including utility relocations. Alternative 2 was just over $17,000,000, not including utility relocations and interfering property purchases. Of the two alternatives, the recommended alternative was found to be Alternative 1.

Local Downtown Storm Drains

The calculations for the downtown local storm drains (storm drains other than Redlands Boulevard main line) were based on the Regional Alternative 1 alignment. In XP-SWMM, all storm drains and laterals were evaluated in one comprehensive model. Since the goal of the downtown is to minimize flooding, these facilities were sized for the 100-year storm event. Unlike local storm drains in the other watersheds, where systems were sized in WSPGW or FlowMaster, this area was evaluated in XP-SWMM.

RBF
A Baker Company

0 600'
APPROXIMATE

5/15/14 JN 138509-20104 MAS

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

Regional Proposed Condition (Alternative 1)

Figure 3-3

RBF
A Baker Company

4/17/14 JN 138509-20104 MAS

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

Regional Proposed Condition (Alternative 2)

Figure 3-4

Table 3-8: Downtown Regional Alternative Estimated Cost Comparison Summary

Alternative	Construction Cost Estimate	Notes
1	$14,100,000	Utility relocation not included.
2	$17,100,000	Right-of-way issues & utility relocation not included.

ENR Construction Cost Index = 9750 (April 2014)

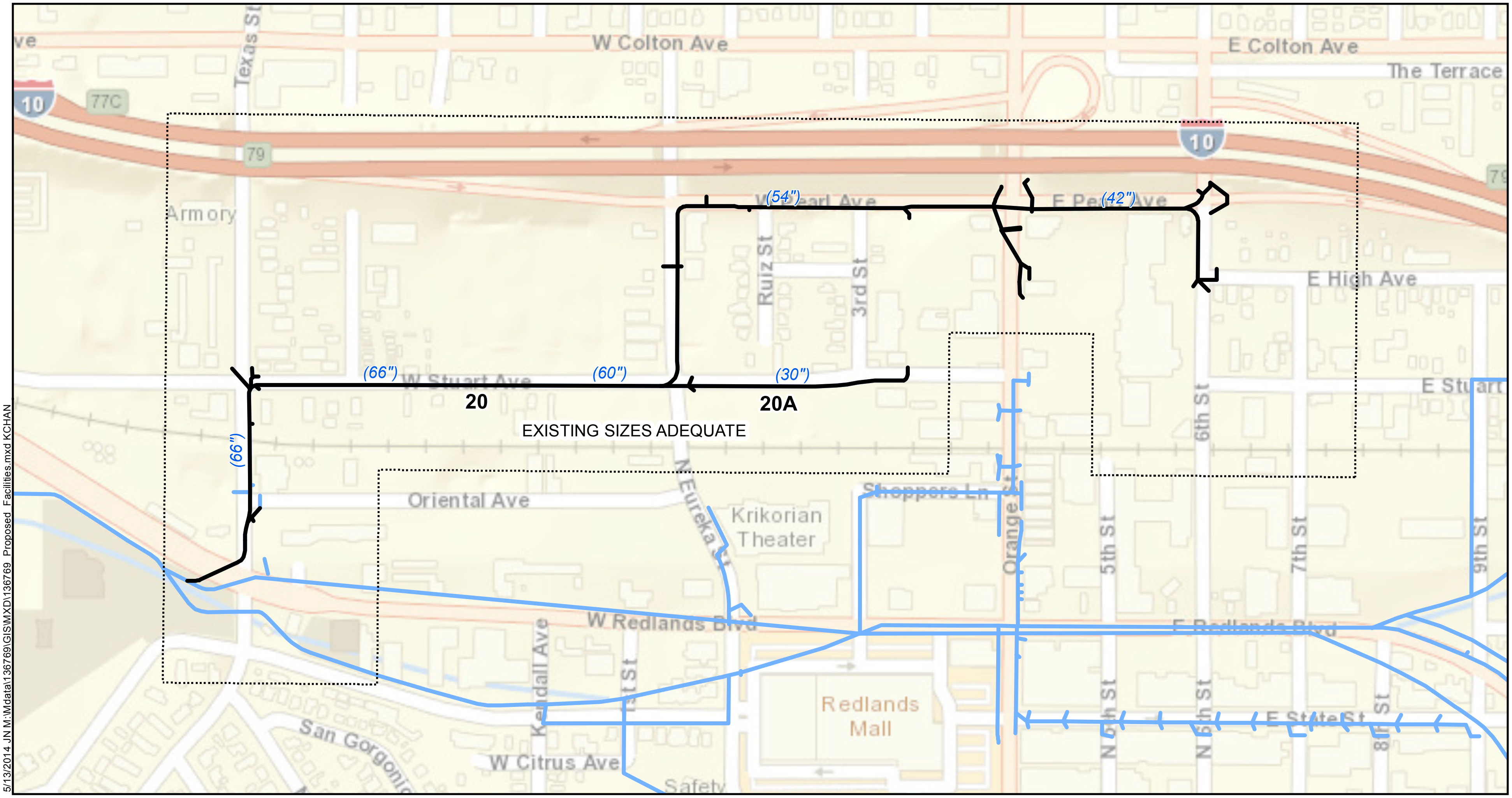
3.3.3 Proposed Improvements

In addition to these proposed regional improvements, the downtown XP-SWMM model also included the local storm drains within the area. Future proposed system calculations for these local storm drains however, were only sized for the recommended alternative *(Alternative 1)*.

Table 3-9 is a summary of the calculated proposed systems for each project area. See Appendix B for the Proposed Conditions XP-SWMM and Street Flow Analyses.

Table 3-9: Downtown Area Proposed Improvements

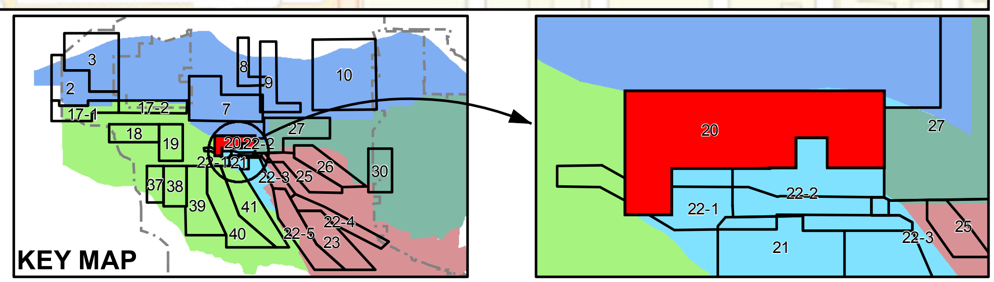
System #	Existing Facility	Proposed Facility	
		Replacement Conduit	
	Conduit Size	Size	Length (ft)
21	Unknown	72	644
22	New	RCB	1,520
	New	RCB	227
22-A	24	36	591
22-B	24	30	924
22-D	15	24	396
22-E	24	36	796
22-K	New	RCB	2,480
22-L	New	72	522
	New	78	780



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING A Baker Company

N

0 495 990 Feet

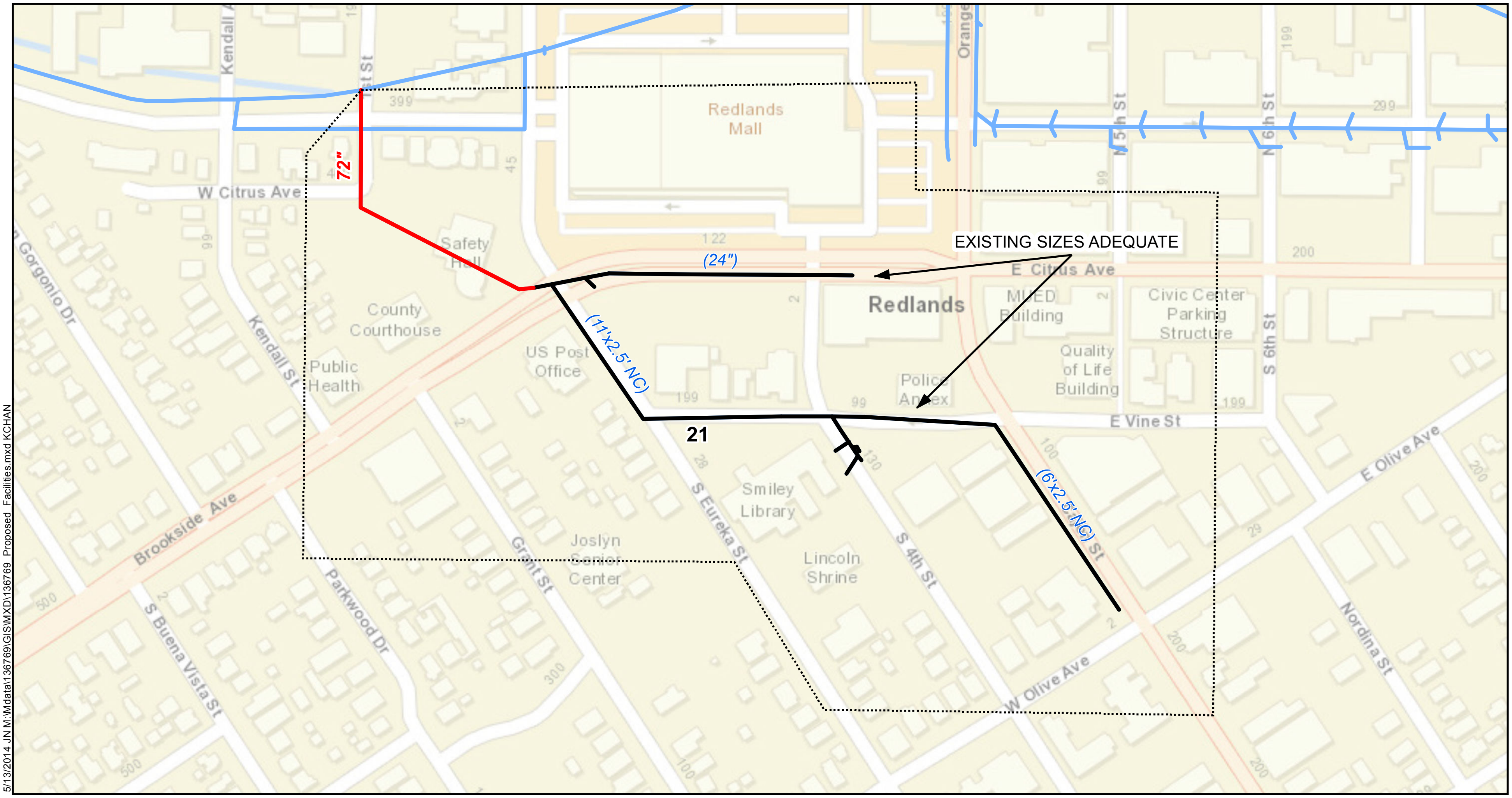
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: DOWNTOWN

MAIN STORM DRAIN FACILITIES - PROJECT AREA 20

FIGURE 3-5A



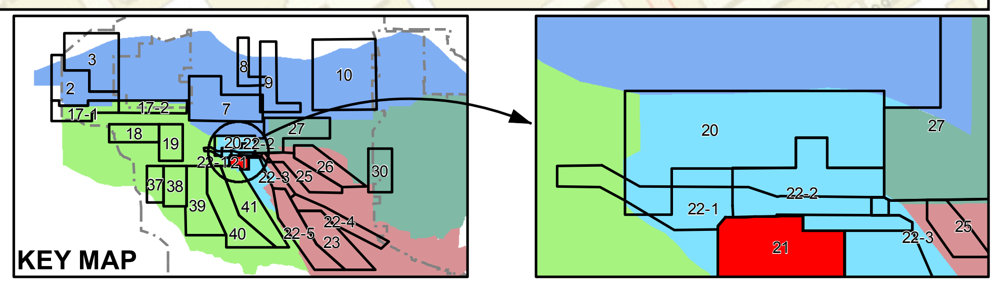
5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

36" Proposed Main Line Sizes
(36") Existing Main Line Sizes
RCC Rectangular Concrete Channel (W'xH')
NC Natural Channel (W'xH')
2A Storm Drain Facility ID
Proposed Storm Drain Facility
Existing Storm Drain Facility
Storm Drain Facilities Shown Elsewhere

City Boundary
Exhibit Focus Area

Mission Zanja
Reservoir Canyon
Downtown
North City
South City



RBF CONSULTING A Baker Company

N

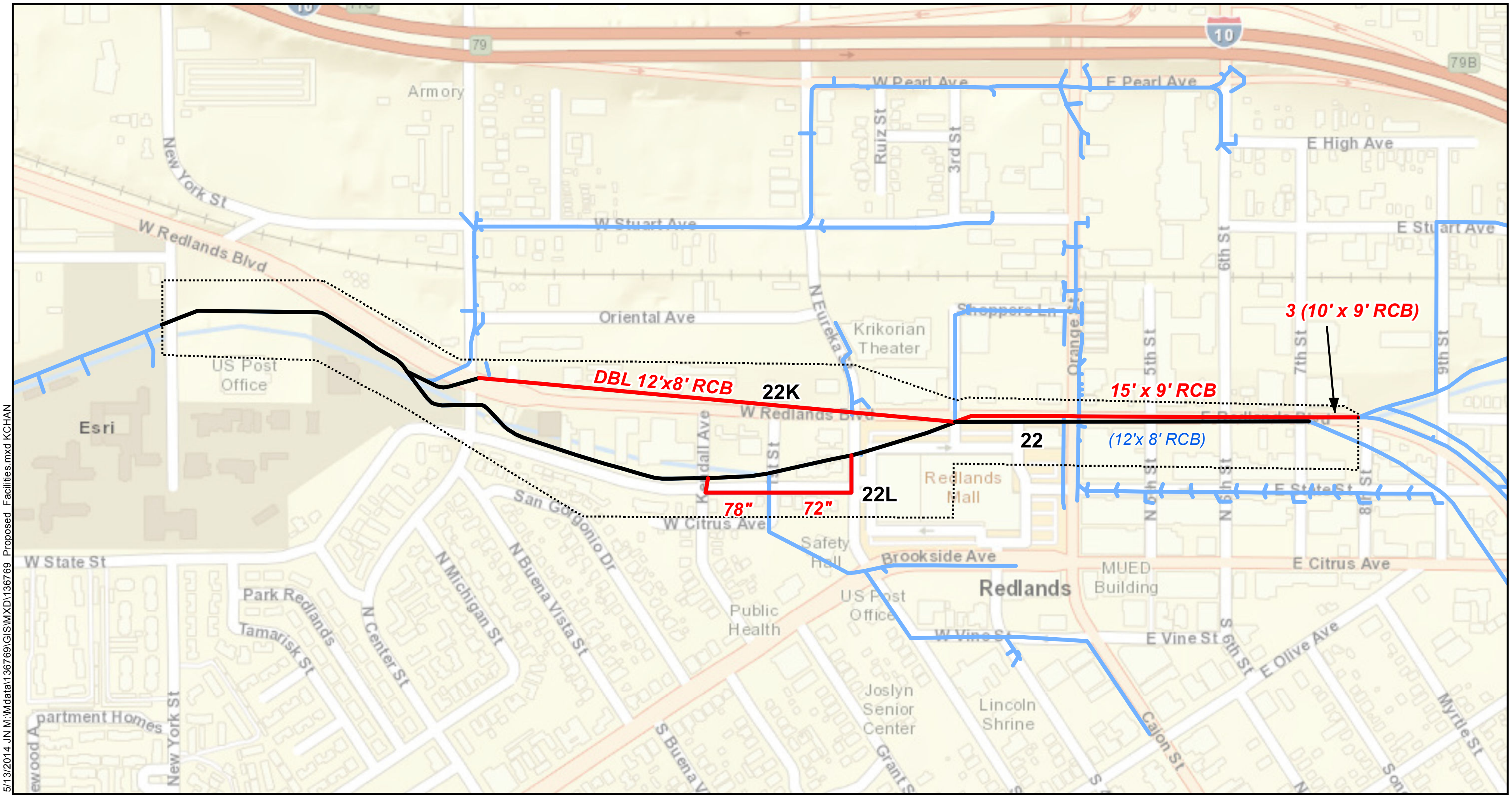
0 312.5 625 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: DOWNTOWN

MAIN STORM DRAIN FACILITIES - PROJECT AREA 21

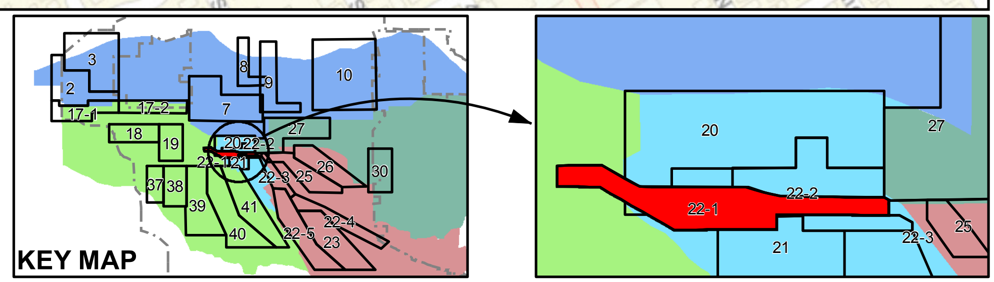
FIGURE 3-5B



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING A Baker Company

N

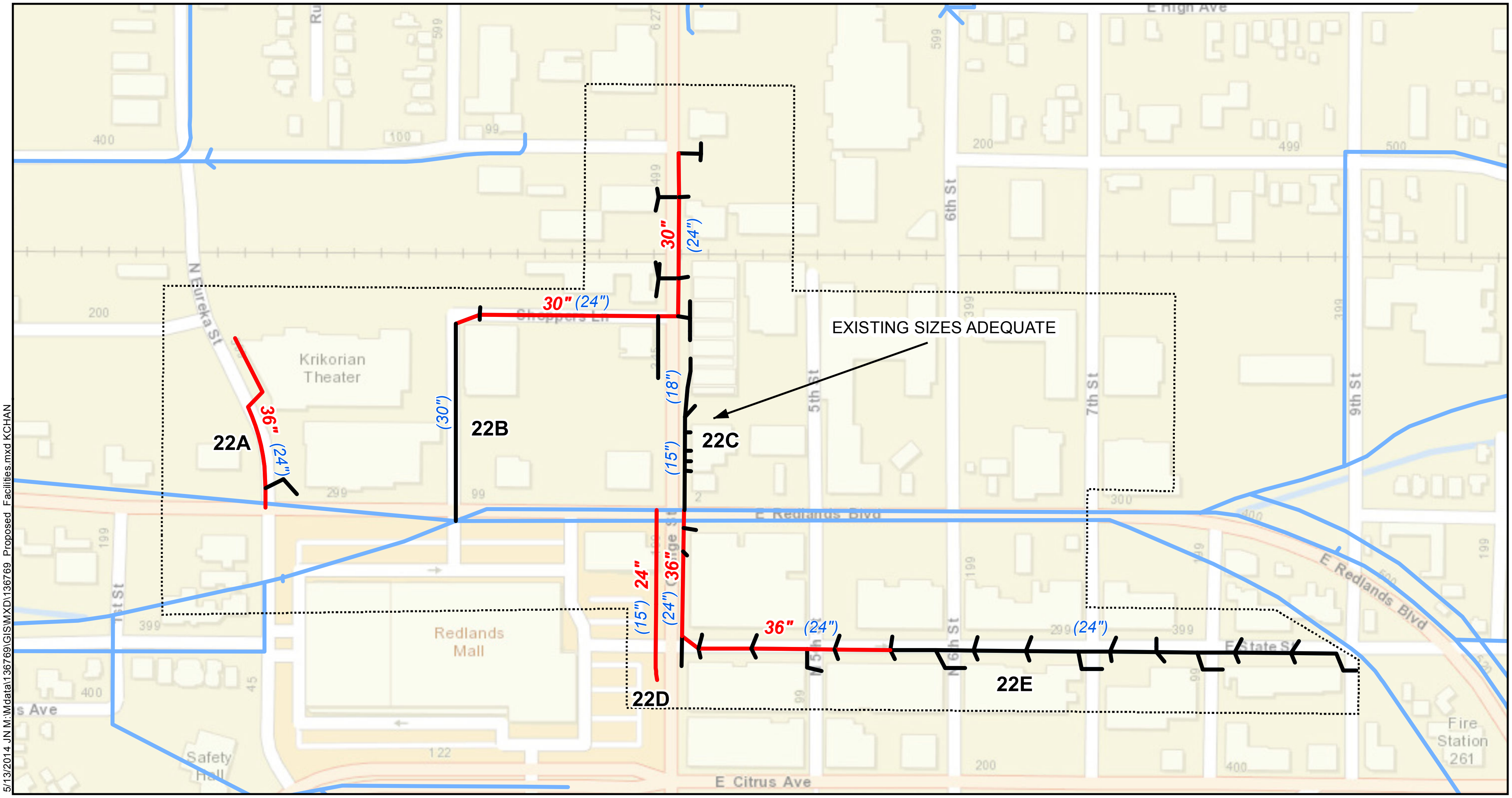
0 625 1,250 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: DOWNTOWN

MAIN STORM DRAIN FACILITIES - PROJECT AREA 22-1

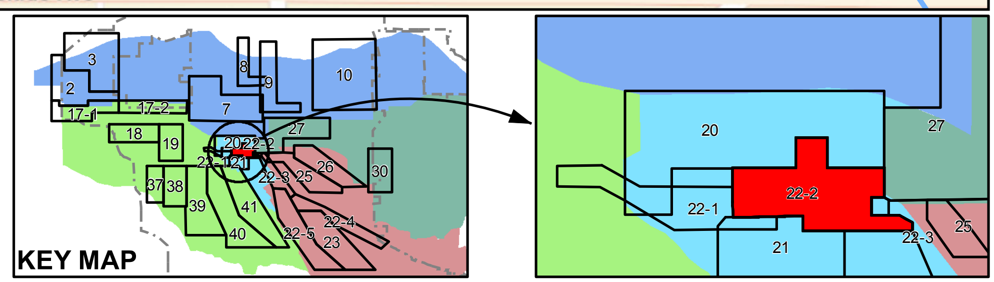
FIGURE 3-5C



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



N

0 337.5 675 Feet

RBF CONSULTING A Baker Company

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: DOWNTOWN

MAIN STORM DRAIN FACILITIES - PROJECT AREA 22-2

FIGURE 3-5D

3.3.4 Cost Estimates

For each system, RBF has provided a recommendation for proposed storm drain facility replacement. Table 3-10 gives a summary of the construction cost estimates and the recommended system within the Downtown Area. See Appendix C for detailed cost estimates.

Table 3-10: Downtown Drainage Area Cost Estimate Summary

System No.	Recommended System Diameter (inches)	Total Project Cost (2014 $)
21	72	$300,000
22	(3) 10w x 9'w RCB	$818,000
	15'w x 9h RCB'	$1,824,000
22-A	36	$170,000
22-B	30	$191,000
22-D	24	$75,000
22-E	36	$229,000
22-K	(2) 12'w x 8'h RCB	$5,952,000
22-L	72	$243,000
	78	$404,000
	Total System Cost	**$9,906,000**

ENR Construction Cost Index = 9750 (April 2014)

3.4 North City Drainage Area

3.4.1 Hydrologic Analysis

The hydrology analysis was achieved using the County's CSDP#4 and the Rational Method model for each storm event analyzed. The analysis was conducted per the SBCFCD Hydrology Manual and methods discussed in Section 2. A cursory review of the County models was performed to verify accuracy.

Hydrology node numbering conventions are consistent with those found in the CSDP#4 Report. Regional hydrology model results of Area 4 can be found in Appendix A. See Figure 1-3 for the North Area Watershed Map. Table 3-11 below provides a summary of the hydrology analyses results.

Table 3-11: North City Drainage Area Hydrology Summary (AMCII)

Node	Location	Drainage Area (ac)	100-Year Flow (cfs)
North City			
21439	Redlands Blvd/Mission Creek	176.6	300.4
21531	Lugonia Ave/Mission Creek	375.6	442.8
11518	Mountain View Ave/SAR	427.3	605.0
11507	Palmetto Ave/SAR	254.9	370.7

3.4.2 Hydraulic Analysis

The North City area contains both open channel and subsurface storm drain facilities. The facilities located within the North City generally drain to the Santa Ana River. This area is bound by the I-10 Freeway to the south and the Santa Ana River to the north. This area is bisected by the SR-210 Freeway. East of the SR-210, the watershed consists primarily of residential land use. To the west of SR-210, most of the land use consists of industrial and agricultural. A small portion of this area drains to an open channel that runs south to north alongside the SR-210.

Along the south-western boundary of the North area, some of the flows south of Lugonia Avenue drain into a Caltrans owned storm drain facility along the I-10 freeway. This section of storm drain was not included in this analysis.

Most of the facilities in North City were calculated using WSPGW. Tailwater conditions for the drainage facilities discharging to the Santa Ana River were taken from the as-built plans.

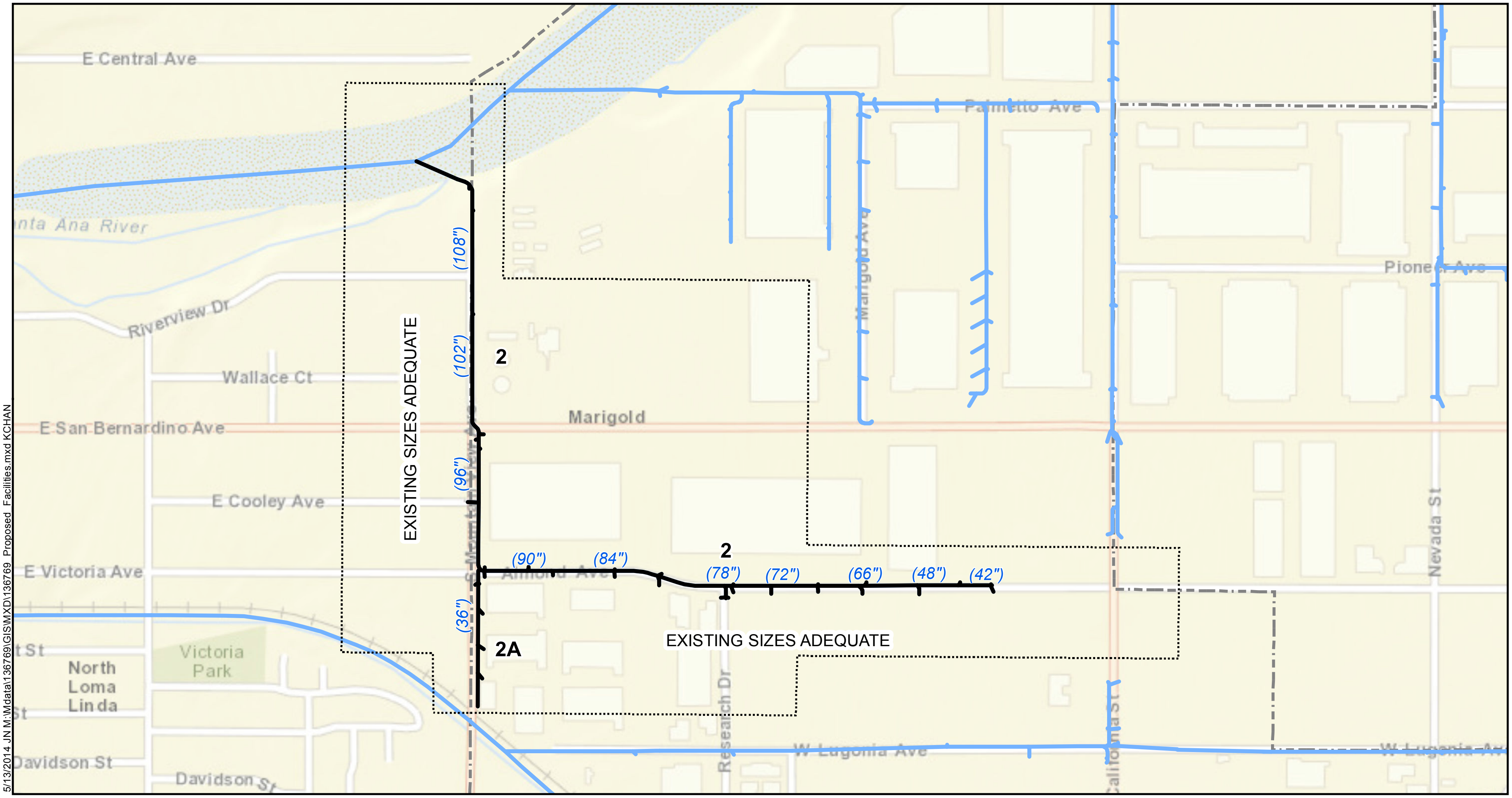
Street flooded width calculations were performed for all streets used as main flow paths in the hydrology analysis. This was done per procedures discussed in section 2.2.2.1. Detailed flooded width analyses results are included in Appendix B.

3.4.3 Proposed Improvements

Table 3-12 is a summary of the calculated proposed systems for each facility within the North City.

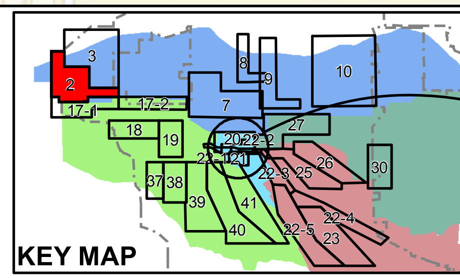
Table 3-12: North City Drainage Area Proposed Improvements

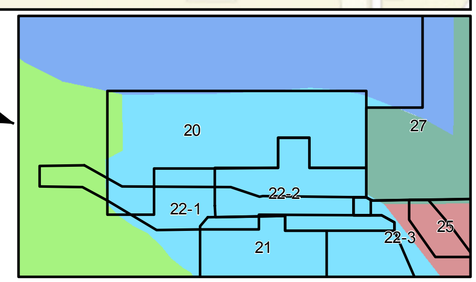
System No.	Existing Facility	Proposed Facility	
		Replacement Conduit	
	Conduit Size	Size	Length (ft)
7	RCB	RCB	117
	66	72	1,989
	57	84	1,238
	New	66	1,001
	New	54	2,665
	New	42	317
7-A	New	30	611
	New	36	1,002
	New	42	3,348
7-B	New	48	2,047
	New	60	1,313
	New	72	4,211
8	Unknown	30	486
	Unknown	36	1,415
	Unknown	42	249
	Unknown	48	3,750
9	New	42	978
	New	54	1,910
	New	66	4,606
	New	72	992
10	New	36	40
	New	42	1,372
	New	54	628
	New	60	352
	New	66	3,608
	RCB	RCB	1,785
10-B	New	42	1,346
	New	54	5,857



LEGEND

- 36" Proposed Main Line Sizes
- (36") Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- 2A Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City





RBF CONSULTING A Baker Company

N

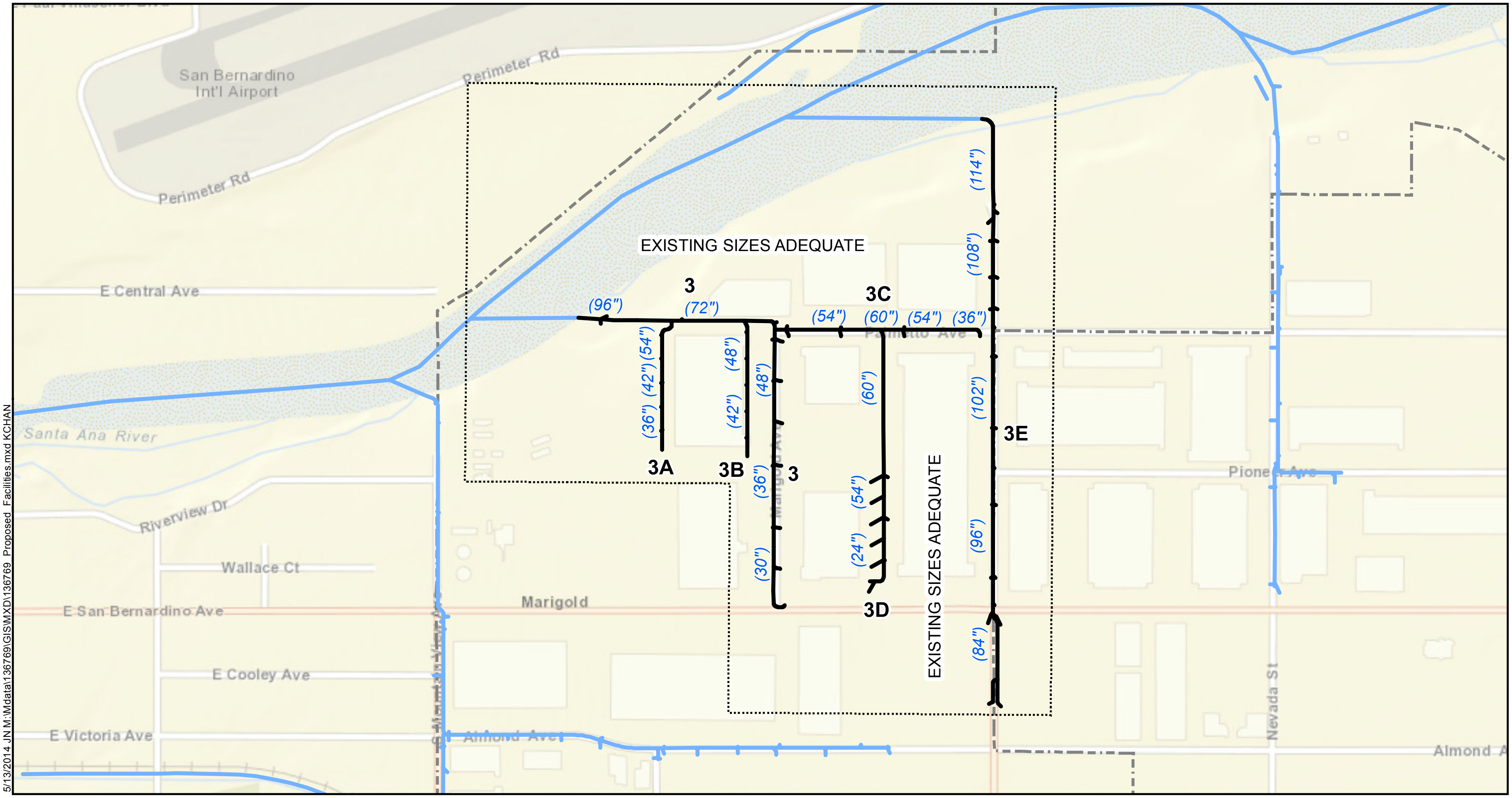
0 1,150 2,300 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: NORTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 2

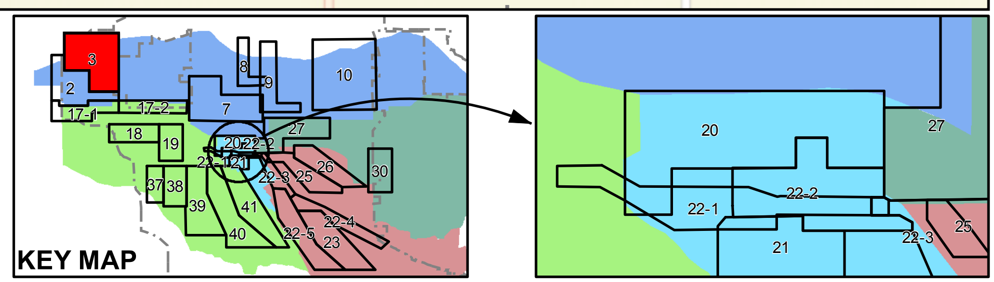
FIGURE 3-6A



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING A Baker Company

N

0 1,350 2,700 Feet

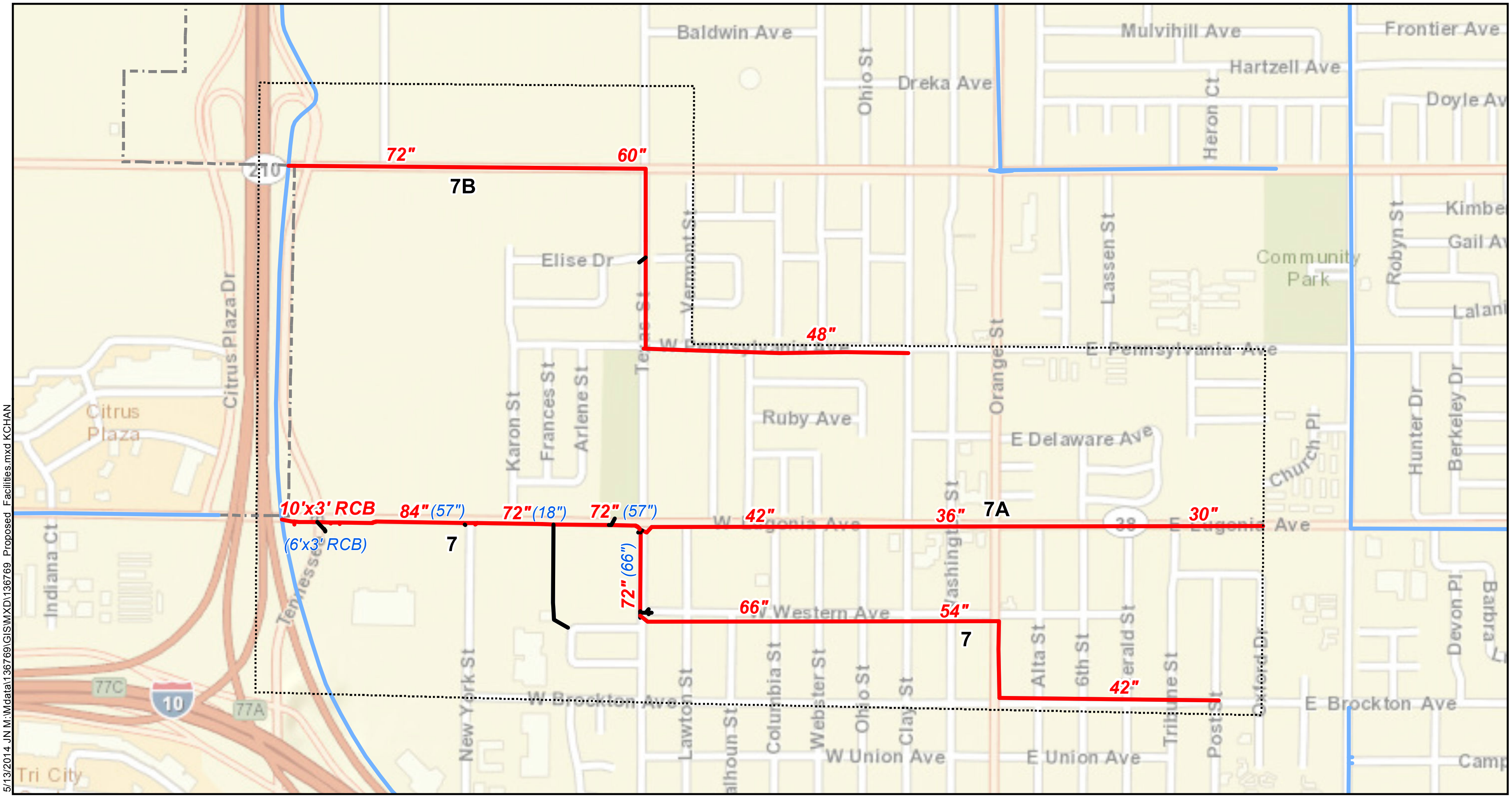
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: NORTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 3

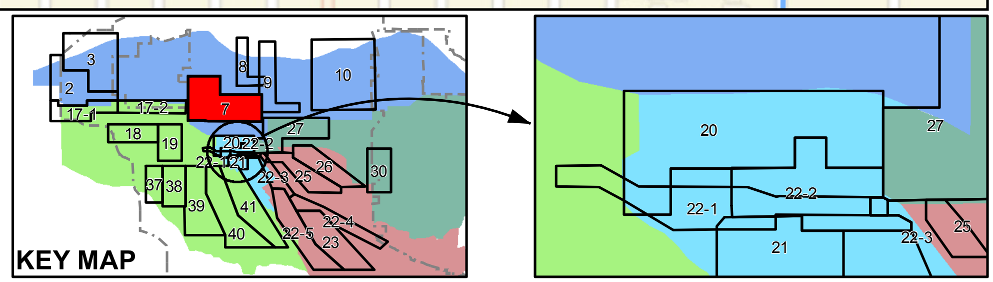
FIGURE 3-6B



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- **36"** Proposed Main Line Sizes
- (36") Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING
A Baker Company

N

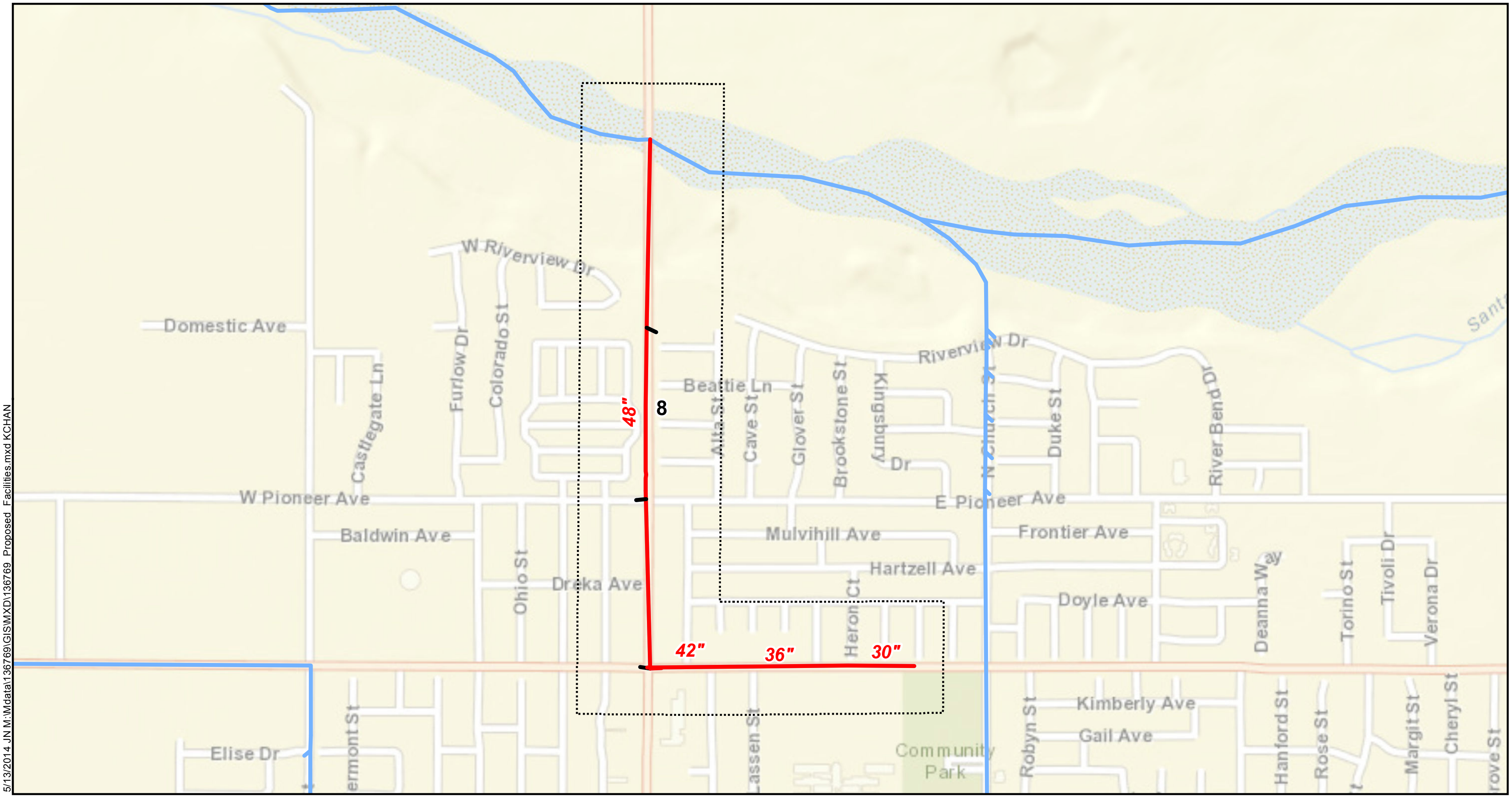
0 1,050 2,100 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: NORTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 7

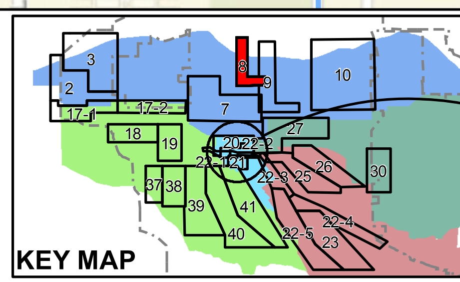
FIGURE 3-6C

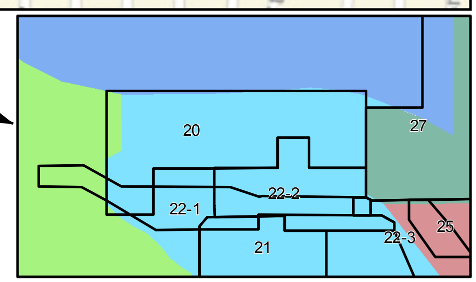


5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- 2A Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City





RBF CONSULTING A Baker Company

N

0 1,100 2,200 Feet

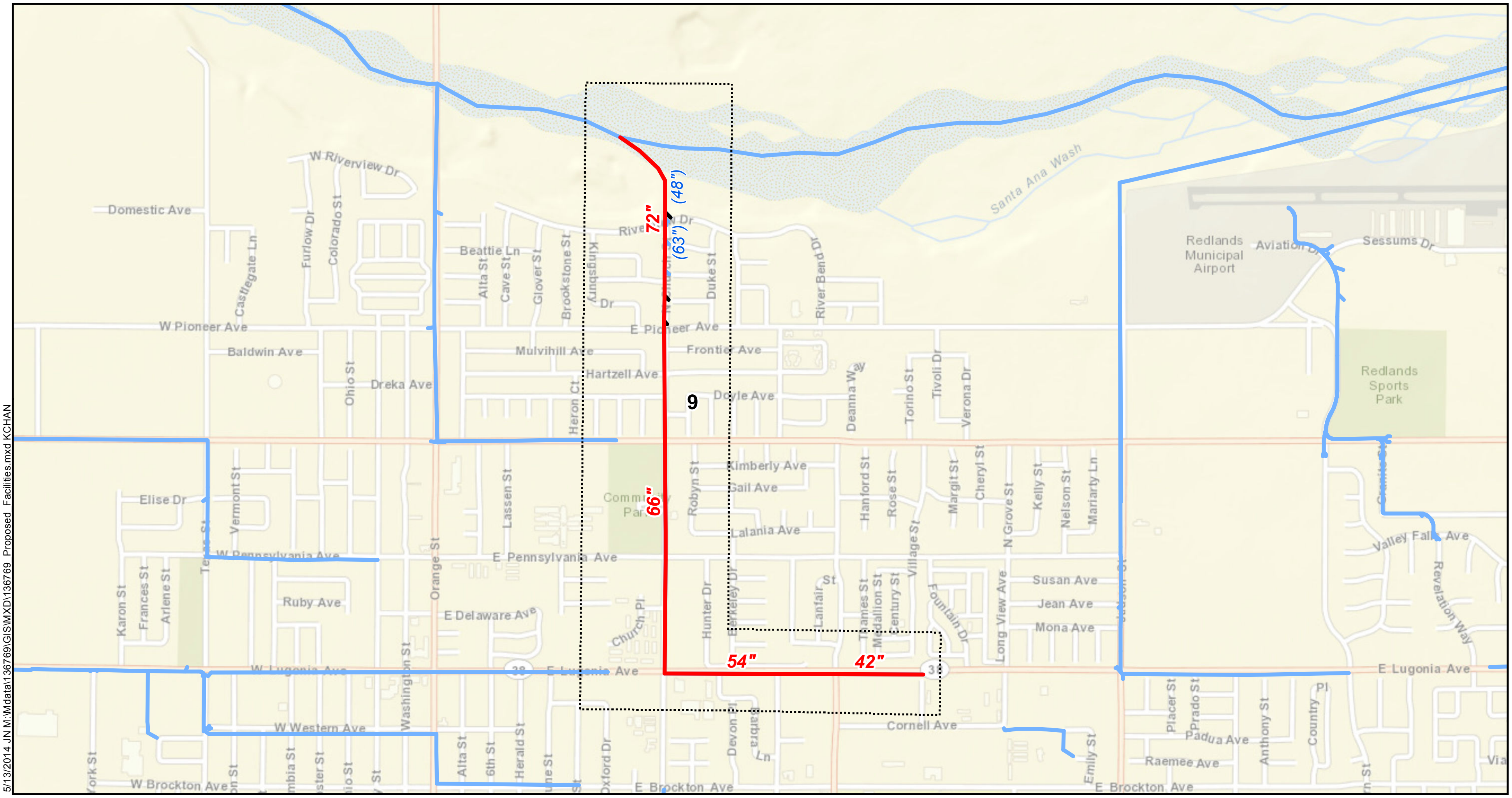
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: NORTH CITY

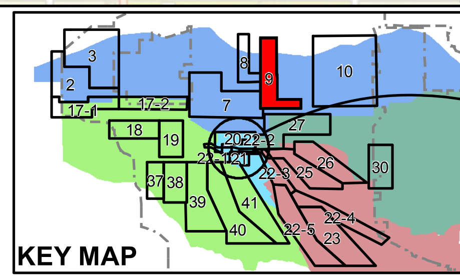
MAIN STORM DRAIN FACILITIES - PROJECT AREA 8

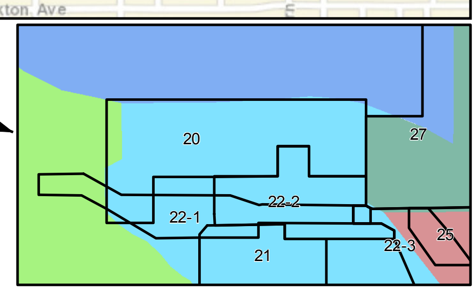
FIGURE 3-6D



LEGEND

36" Proposed Main Line Sizes
(36") Existing Main Line Sizes
RCC Rectangular Concrete Channel (W'xH')
NC Natural Channel (W'xH')
2A Storm Drain Facility ID
Proposed Storm Drain Facility
Existing Storm Drain Facility
Storm Drain Facilities Shown Elsewhere
City Boundary
Exhibit Focus Area
Mission Zanja
Reservoir Canyon
Downtown
North City
South City





RBF CONSULTING A Baker Company

N

0 1,625 3,250 Feet

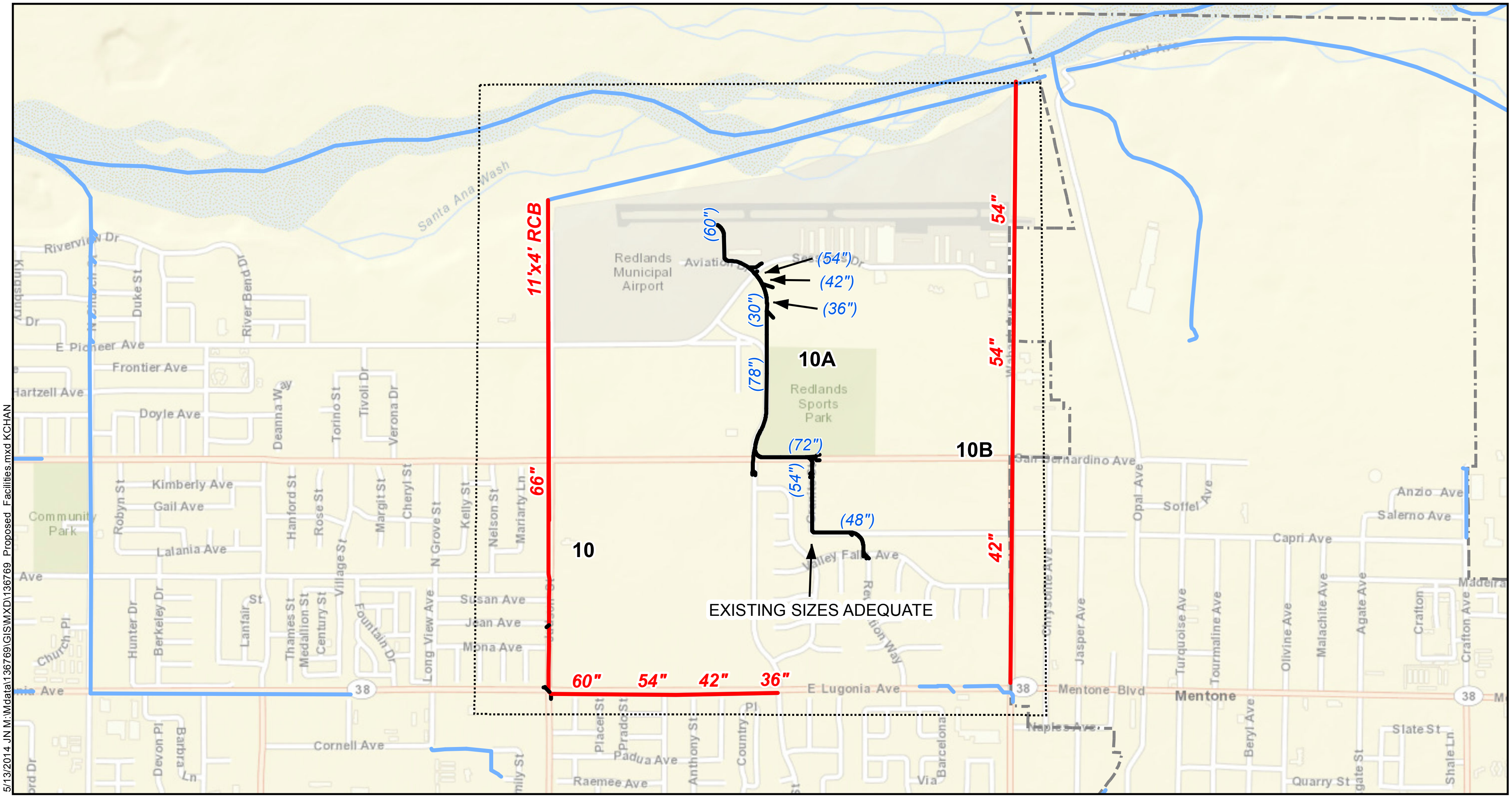
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: NORTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 9

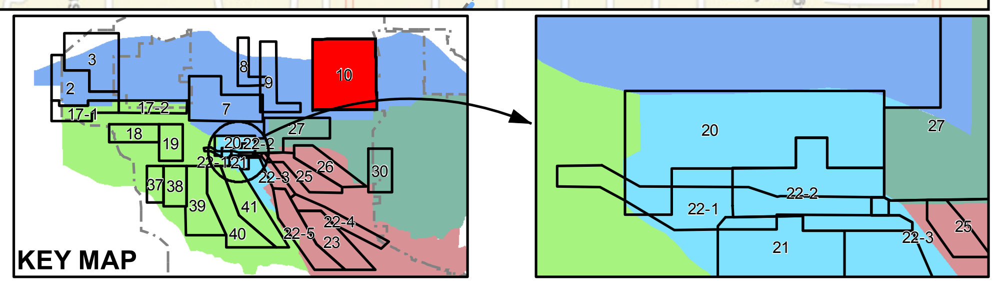
FIGURE 3-6E

5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN



LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING A Baker Company

0 1,625 3,250 Feet

N

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: NORTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 10

FIGURE 3-6F

5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

3.4.4 Cost Estimates

For each system, RBF has provided a recommendation for proposed storm drain facility replacement.

Table 3-13 gives a summary of the construction cost estimates and the recommended system within this drainage area. See Appendix C for detailed cost estimates.

Table 3-13: North City Drainage Area Cost Estimate Summary

System No.	Recommended System Diameter (inches)	Total Project Cost (2014 $)
7	42	$100,000
	54	$920,000
	66	$432,000
	72	$926,000
	84	$697,000
	10’w x 3’h RCB	$140,000
7-A	30	$126,000
	36	$288,000
	42	$1,059,000
7-B	48	$683,000
	60	$521,000
	72	$1,961,000
8	30	$101,000
	36	$407,000
	42	$79,000
	48	$1,251,000
9	42	$309,000
	54	$659,000
	66	$1,986,000
	72	$462,000
10	36	$12,000
	42	$434,000
	54	$217,000

System No.	Recommended System Diameter (inches)	Total Project Cost (2014 $)
	60	$140,000
	66	$1,556,000
	RCB	$2,142,000
10-B	42	$426,000
	54	$2,021,000
Total System Cost		**$20,053,000**

3.5 South City Drainage Area

3.5.1 Hydrologic Analysis

The hydrology analysis was achieved using the County's CSDP#4 and the Rational Method model for each storm event analyzed. The analysis was conducted per the SBCFCD Hydrology Manual and methods discussed in Section 2. A cursory review of the County models was performed to verify accuracy.

Hydrology node numbering conventions are consistent with those found in the CSDP#4 Report. Regional hydrology model results can be found in Appendix A. See Figure 1-3 for the South City Watershed Map. Table 3-14 below provides a summary of the hydrology analyses results.

Table 3-14: South City Drainage Area Hydrology Summary (AMCII)

Node	Location	Drainage Area (ac)	100-Year Flow (cfs)
South City			
21167	Melbury Pl./Olive Ave	741.4	955.1
21361	Tennessee St/Orange Ave	1442.1	1711.9
21378	Kansas St/Orange Ave	2030.2	2451.8
21418	Between Alabama and Kansas St	2200.9	2563.4
21419	Iowa St./Orange Ave	2470.2	2771.4

3.5.2 Hydraulic Analysis

South City contains both open channel and subsurface storm drain facilities. The facilities generally drain to Mission Creek, south of Citrus Avenue/West State Street. This area is bound by the I-10 Freeway to the south and the Santa Ana River to the north. South City is bisected by the foothills to the south, Reservoir Canyon Area to the east, and North City to the north.

Most facilities within this drainage area flow into the open channel facility located along, and adjacent to, Orange Avenue. General land uses in this area consist of residential, open space, and agricultural.

The mainline facilities in this area were calculated using WSPGW. Tailwater conditions for the drainage facilities discharging to the Santa Ana River were taken from the as-built plans.

Street flooded width calculations were performed for all streets used as main flow paths in the hydrology analysis. This was done per procedures discussed in section 2.2.2.1. Detailed flooded width analyses results are included in Appendix B.

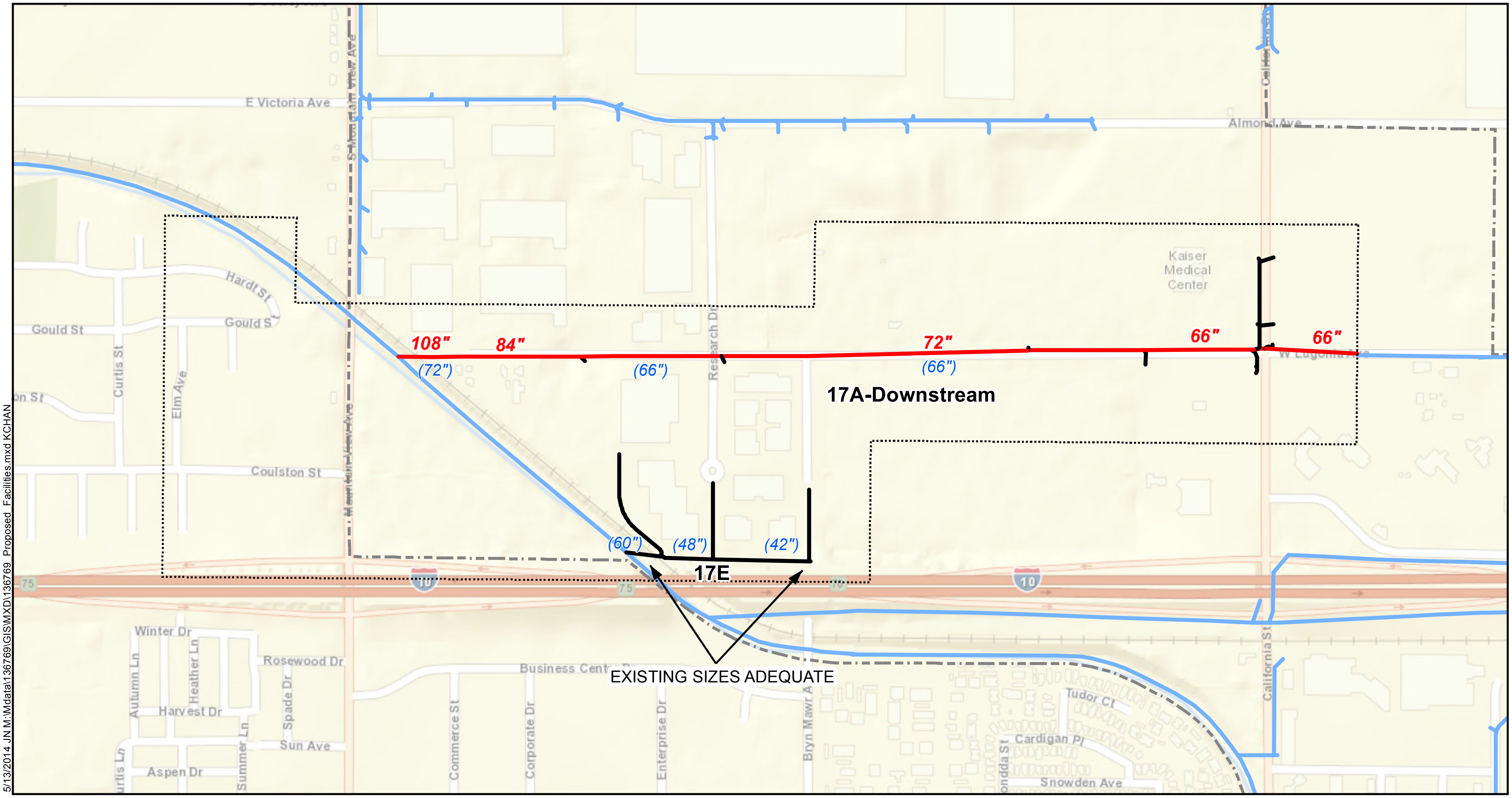
3.5.3 Proposed Improvements

Table 3-15 is a summary of the calculated proposed systems for each facility in the South City drainage area.

Table 3-15: South City Drainage Area Proposed Improvements

System No.	Existing Facility	Proposed Facility	
		Replacement Conduit	
	Conduit Size	Size	Length (ft)
17-B	New	30	334
	New	36	683
17-A	42	48	1,389
	51	60	1,690
	New	66	87
	66	72	3,322
	72	84	185
	72	108	820
18-A	24	36	217
18-A1	New	42	503
18	36	42	612
	36	48	640
	36	RCB	1,331
19	39	60	631
	48	72	2,435
38	New	30	60
	54	60	1,549

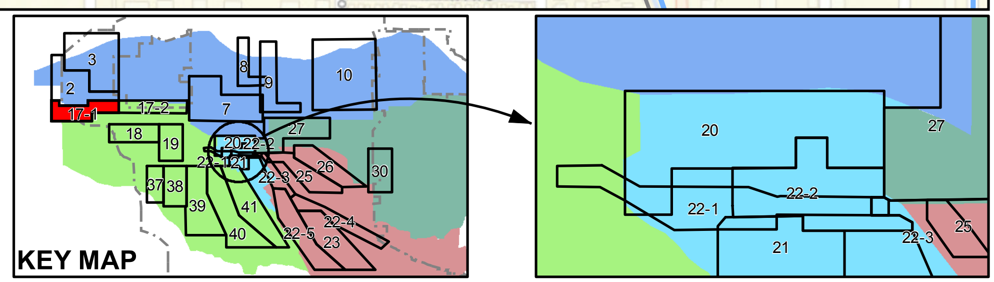
System No.	Existing Facility	Proposed Facility	
		Replacement Conduit	
	Conduit Size	Size	Length (ft)
	54	66	463
38-B	36	60	1,543
39	45	48	1,577
	51	54	1,415
	48	60	192
39-A	New	42	647
	36	48	2,109
	51	54	1,976
39-C	New	30	374
	New	36	308
	New	42	554
40	54	66	572
	54	72	2,010
	RCC	RCC	1,269
	RCB	RCB	399
41	Channel	RCC	1,440
	Channel	RCC	1,350
	Channel	RCC	1,350
	Channel	RCC	2,428
	Channel	RCC	1,425
	Channel	RCC	1,047



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING A Baker Company

N

0 800 1,600 Feet

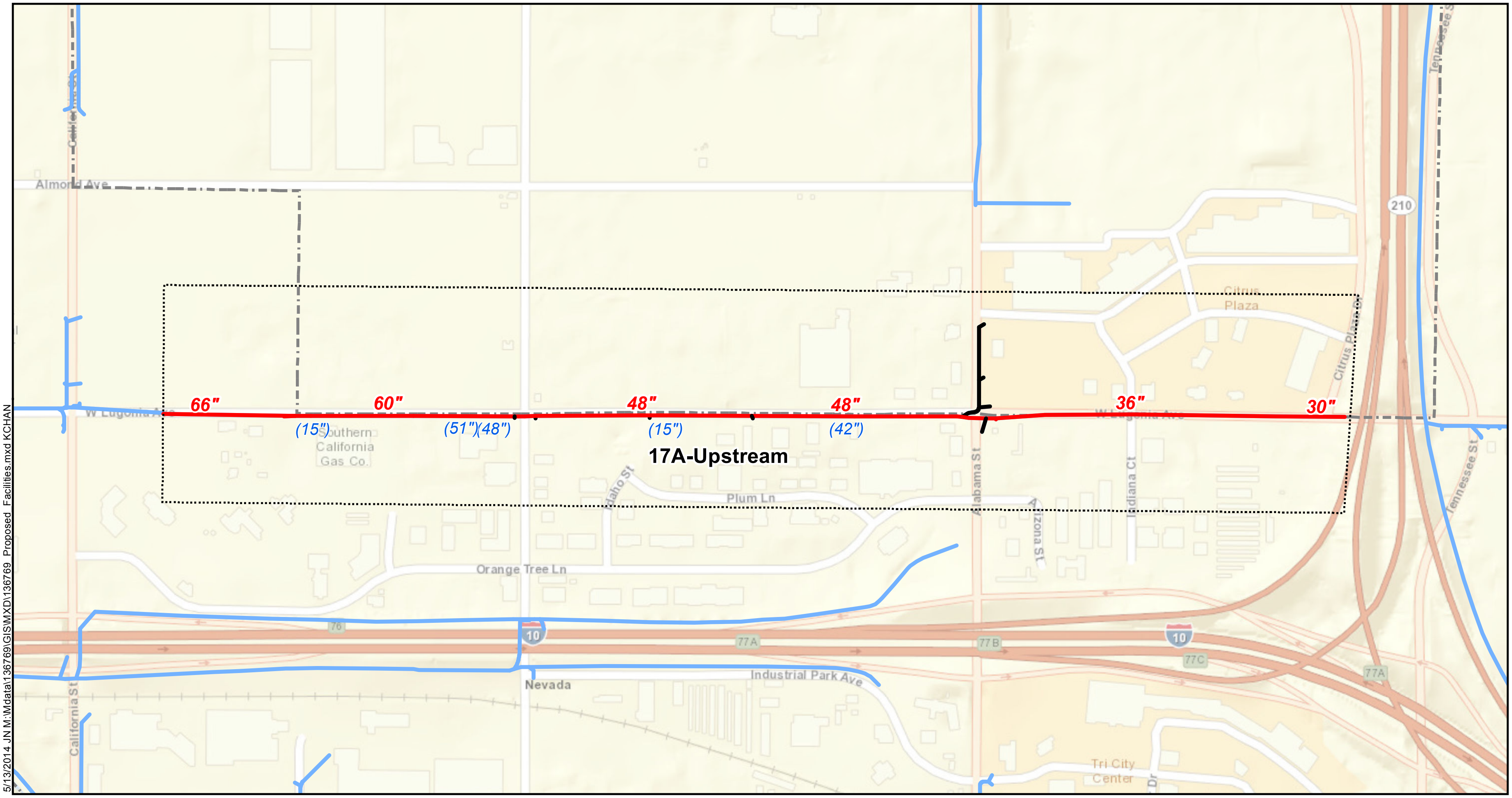
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: SOUTH CITY

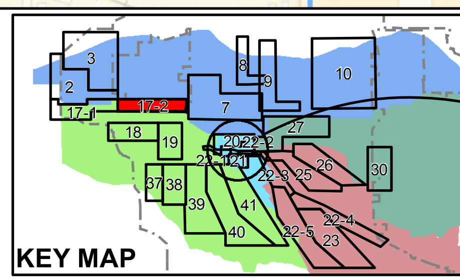
MAIN STORM DRAIN FACILITIES - PROJECT AREA 17-1

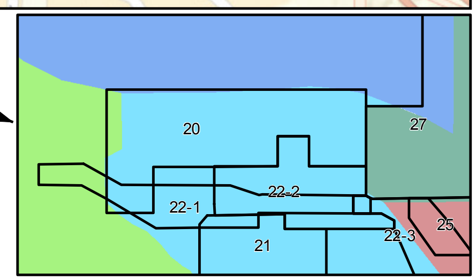
FIGURE 3-7A



LEGEND

36"	Proposed Main Line Sizes
(36")	Existing Main Line Sizes
RCC	Rectangular Concrete Channel (W'xH')
NC	Natural Channel (W'xH')
2A	Storm Drain Facility ID
	Proposed Storm Drain Facility
	Existing Storm Drain Facility
	Storm Drain Facilities Shown Elsewhere
	City Boundary
	Exhibit Focus Area
	Mission Zanja
	Reservoir Canyon
	Downtown
	North City
	South City





RBF CONSULTING A Baker Company

N

0 800 1,600 Feet

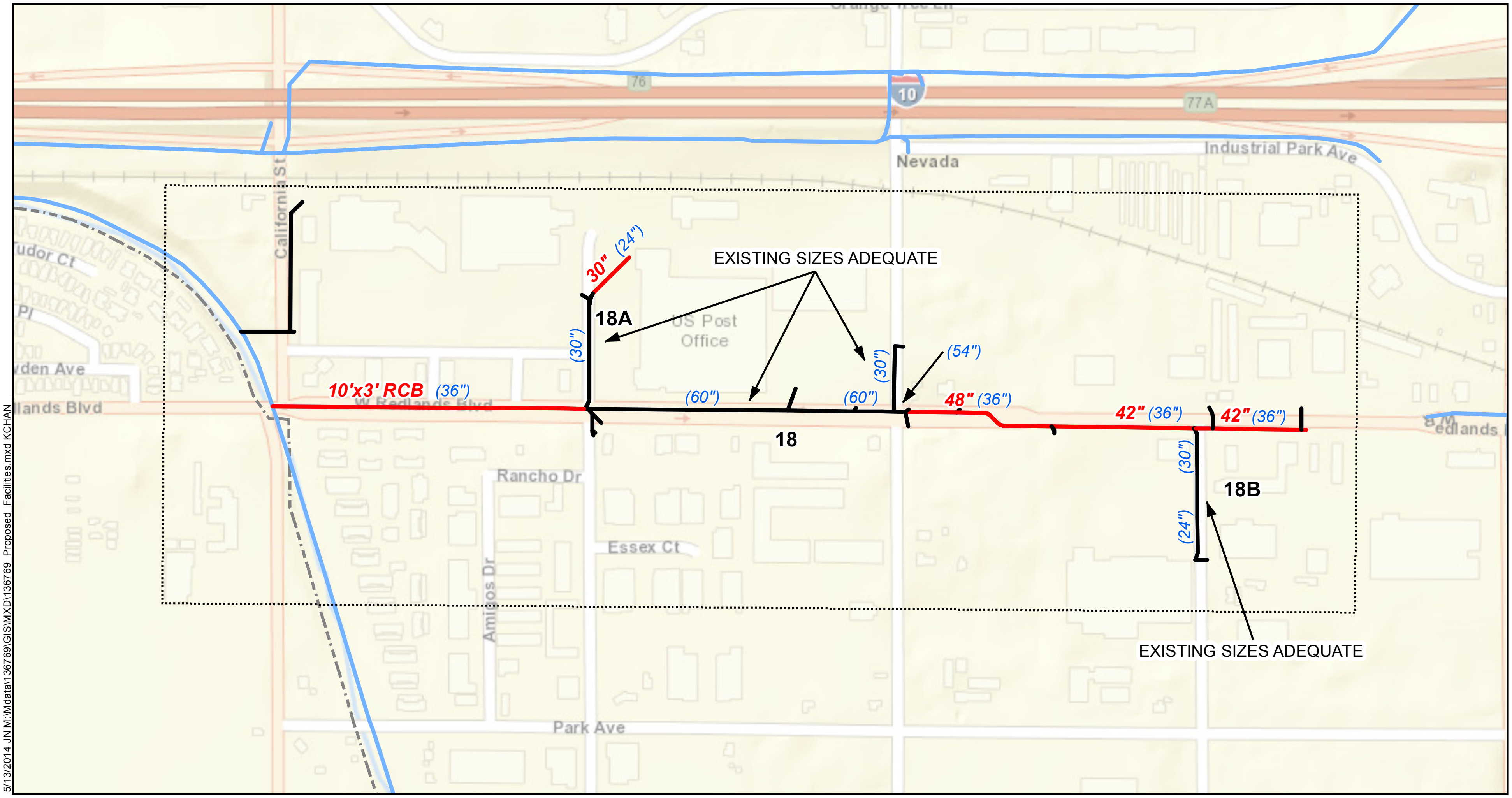
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: SOUTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 17-2

FIGURE 3-7B

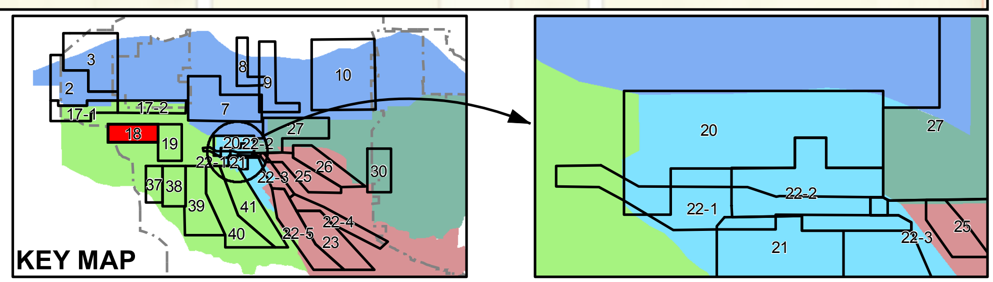
5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- 36" Proposed Main Line Sizes
- (36") Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- 2A Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING A Baker Company

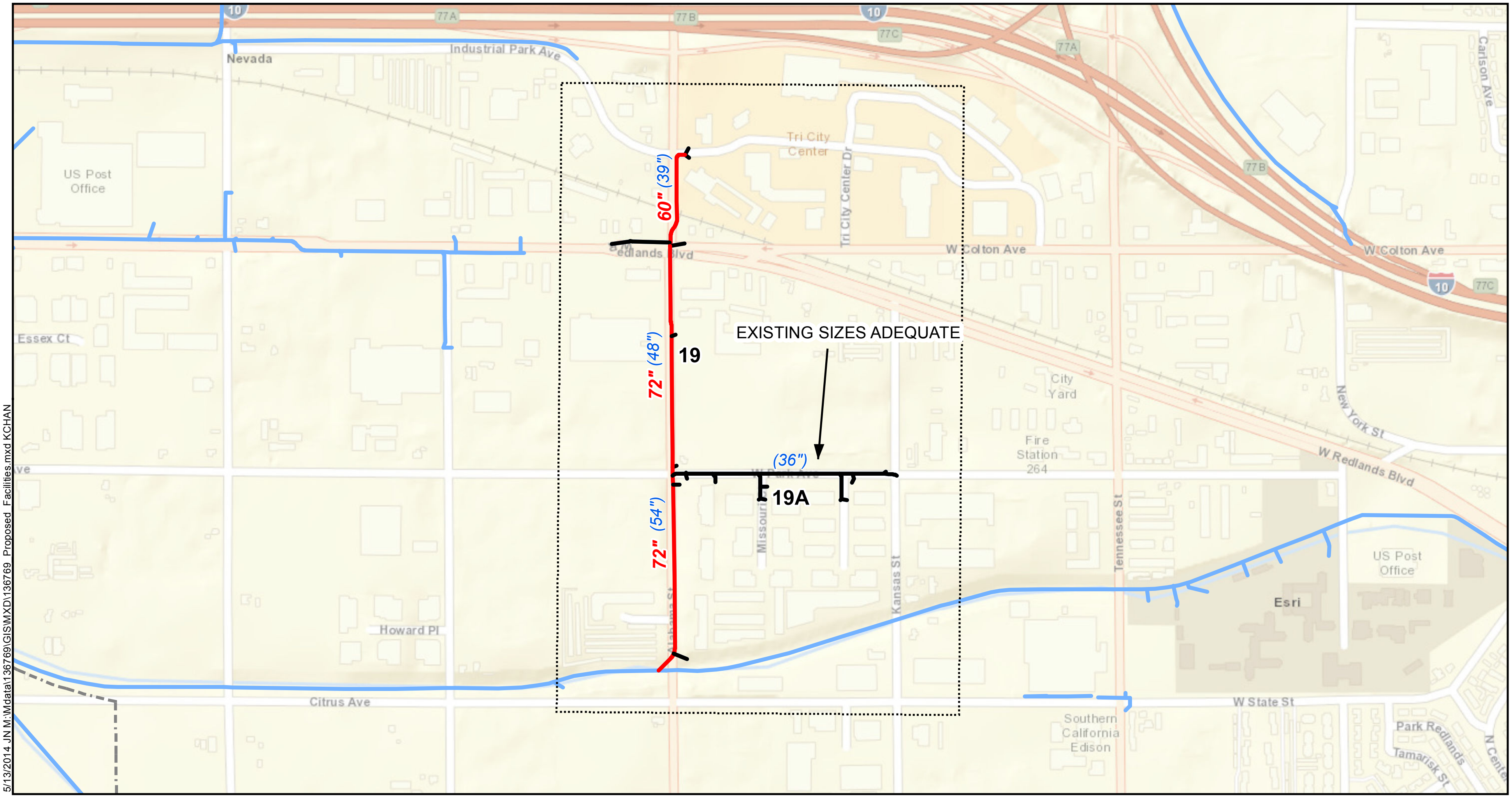
0 600 1,200 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: SOUTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 18

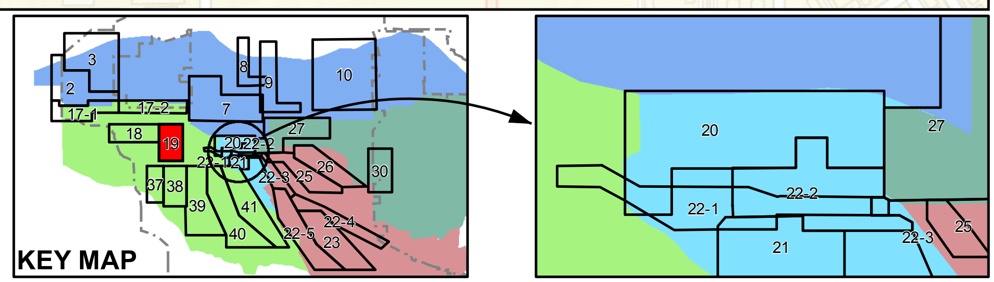
FIGURE 3-7C



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING
A Baker Company

N

0 800 1,600 Feet

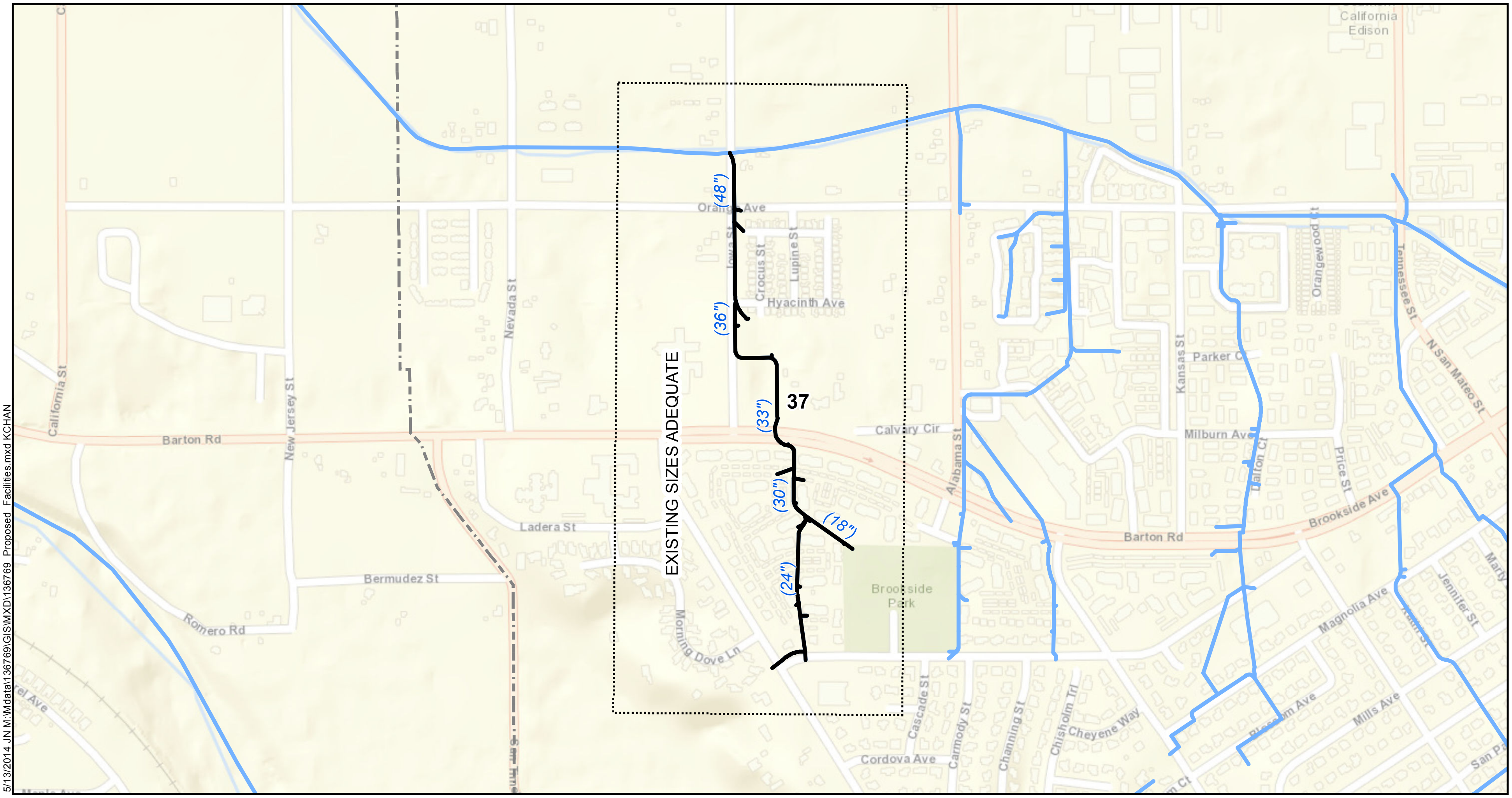
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: SOUTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 19

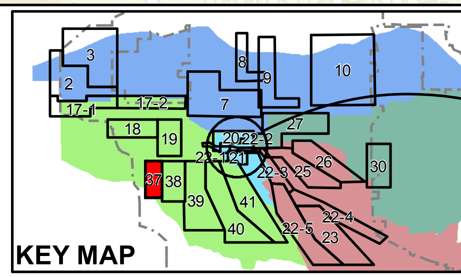
FIGURE 3-7D

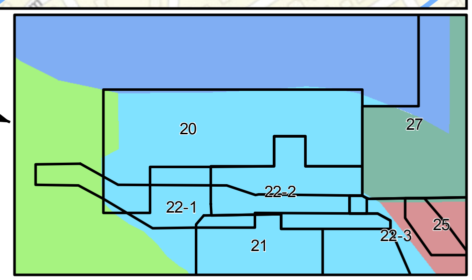


5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City





RBF CONSULTING A Baker Company

N

0 800 1,600 Feet

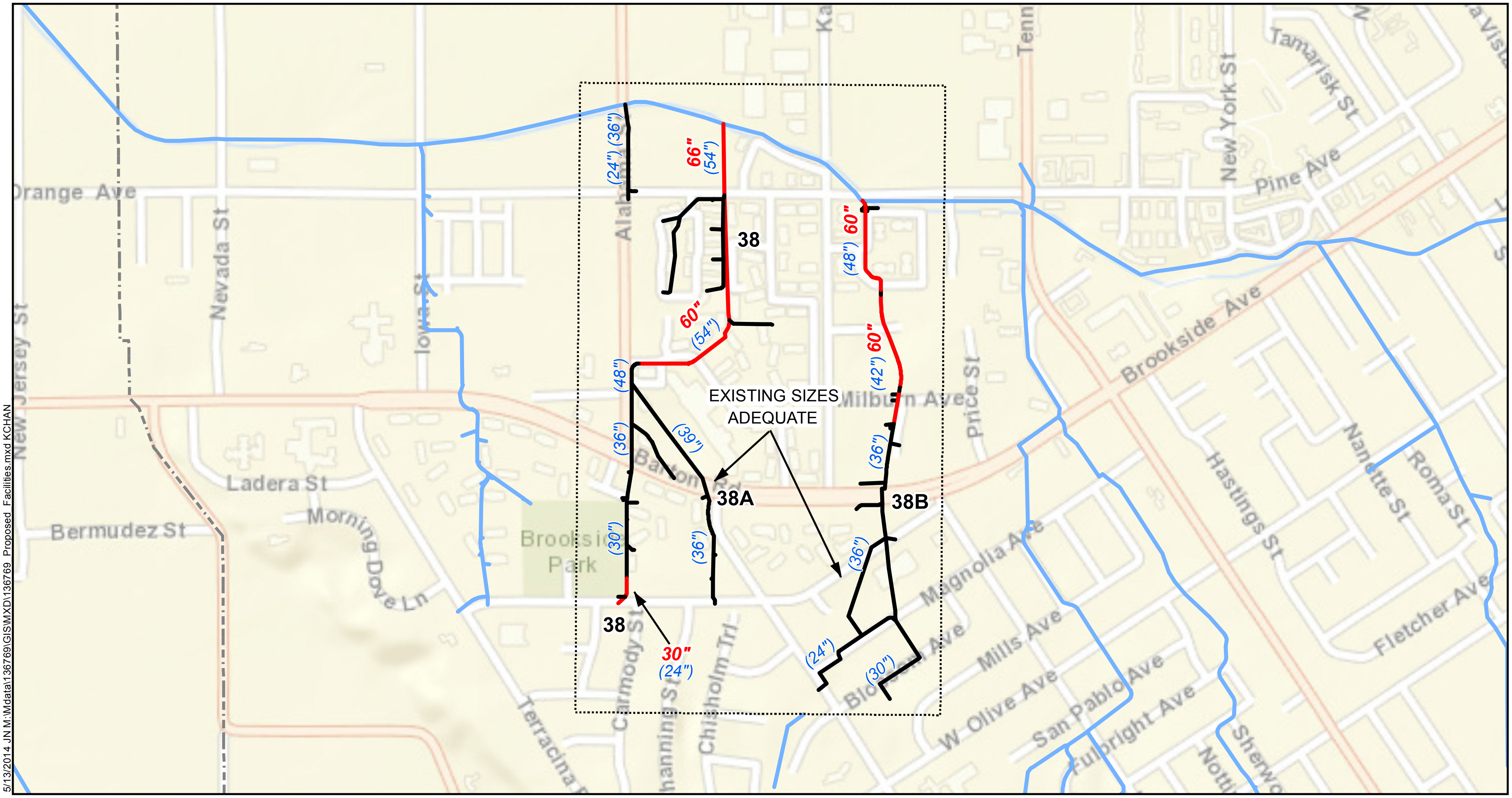
Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

WATERSHED: SOUTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 37

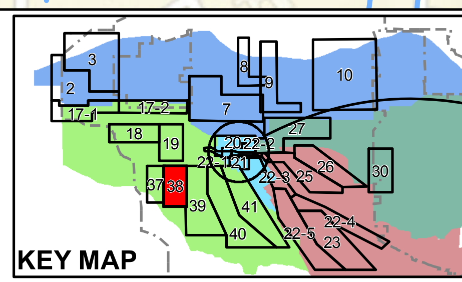
FIGURE 3-7E

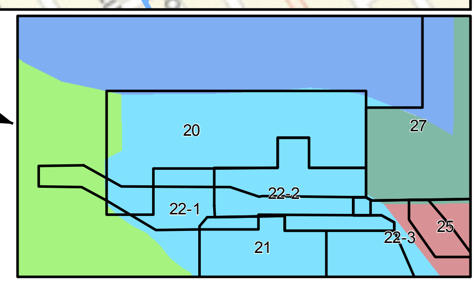


5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City





RBF CONSULTING
A Baker Company

N

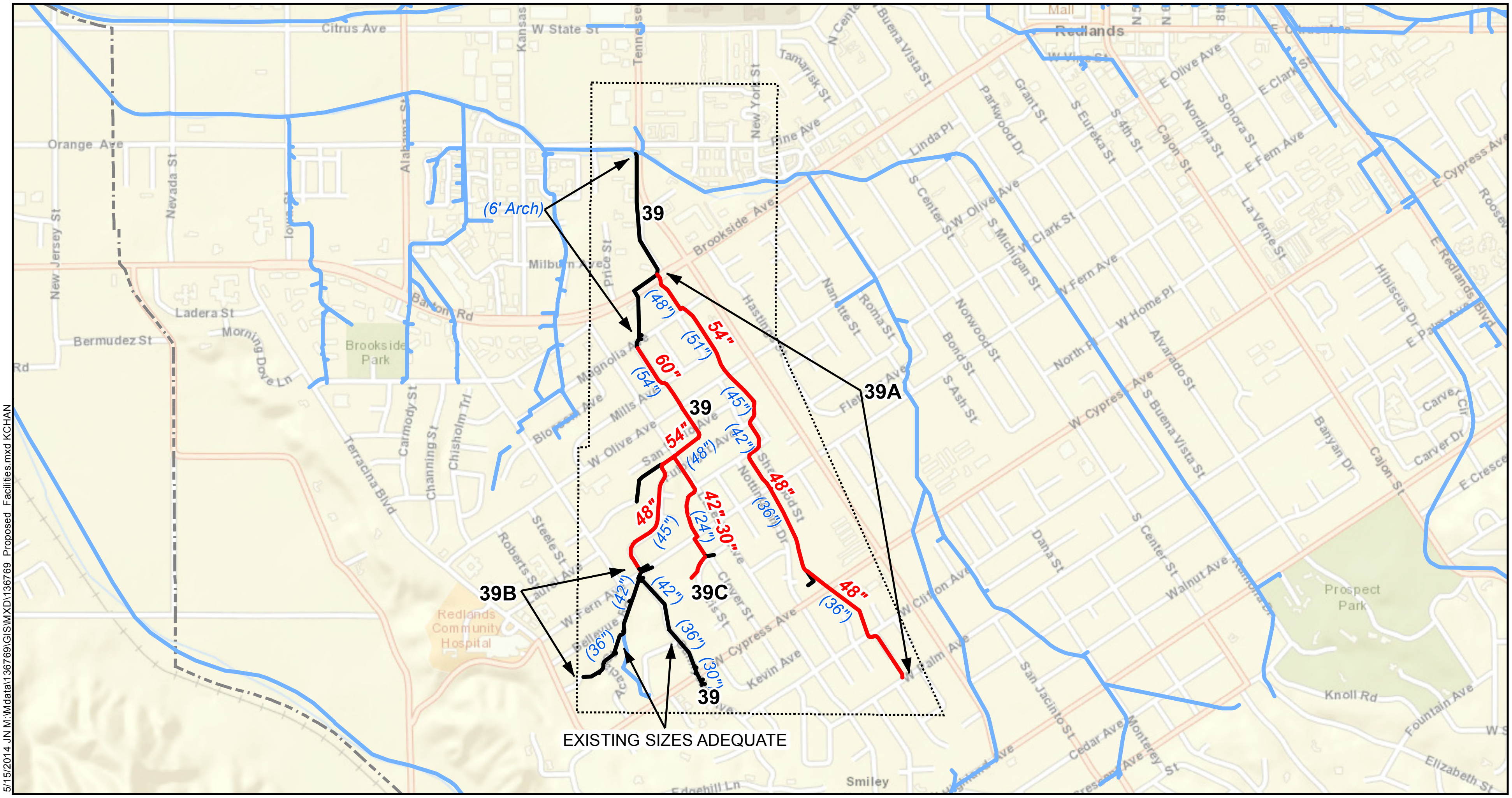
0 900 1,800 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: SOUTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 38

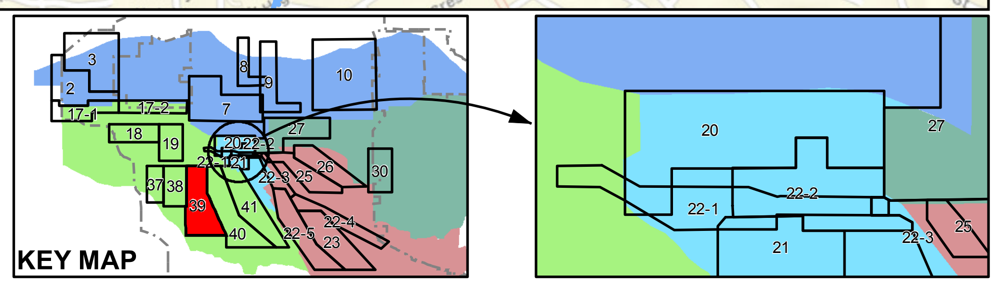
FIGURE 3-7F



5/15/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

36"	Proposed Main Line Sizes
(36")	Existing Main Line Sizes
RCC	Rectangular Concrete Channel (W'xH')
NC	Natural Channel (W'xH')
2A	Storm Drain Facility ID
	Proposed Storm Drain Facility
	Existing Storm Drain Facility
	Storm Drain Facilities Shown Elsewhere
	City Boundary
	Exhibit Focus Area
	Mission Zanja
	Reservoir Canyon
	Downtown
	North City
	South City



RBF CONSULTING
A Baker Company

N

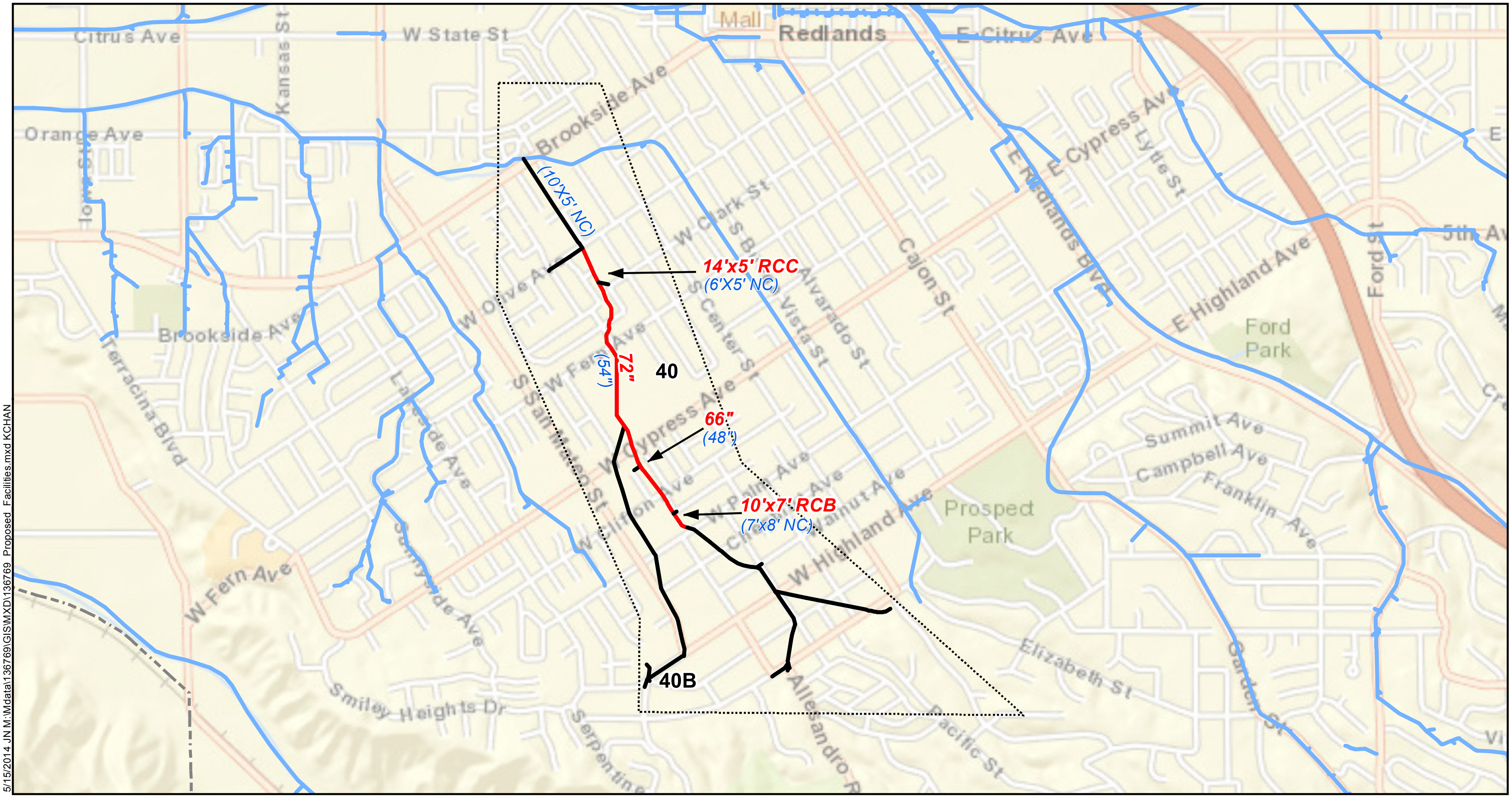
0 1,600 3,200 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: SOUTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 39

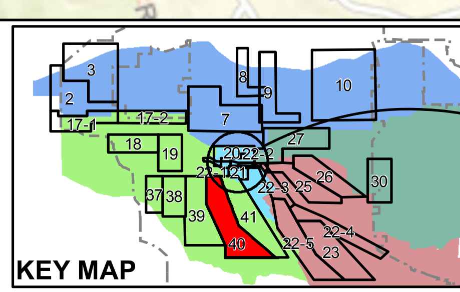
FIGURE 3-7G

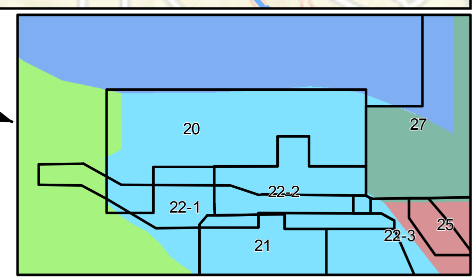


5/15/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City





RBF CONSULTING
A Baker Company

N

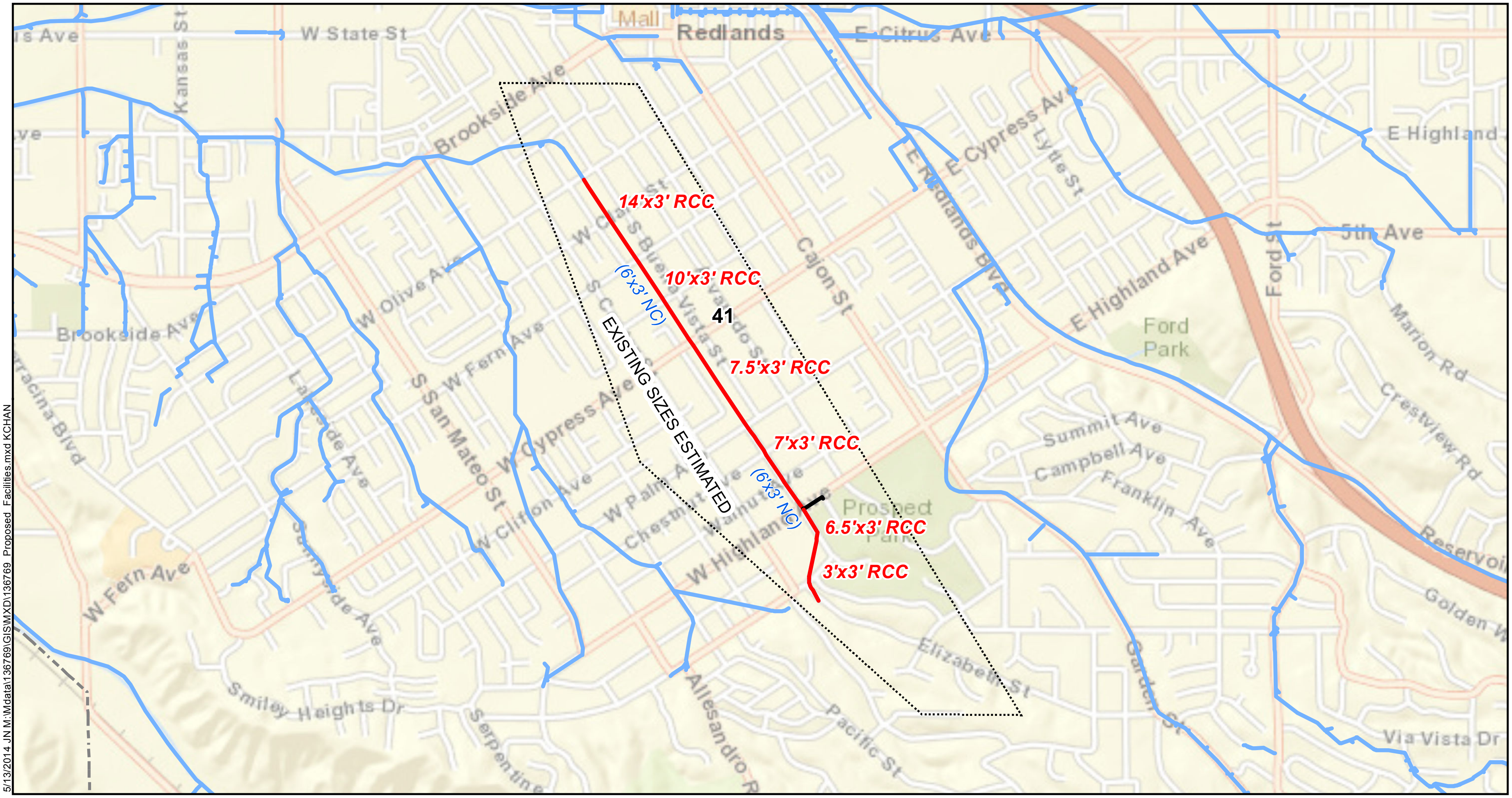
0 1,875 3,750 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: SOUTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 40

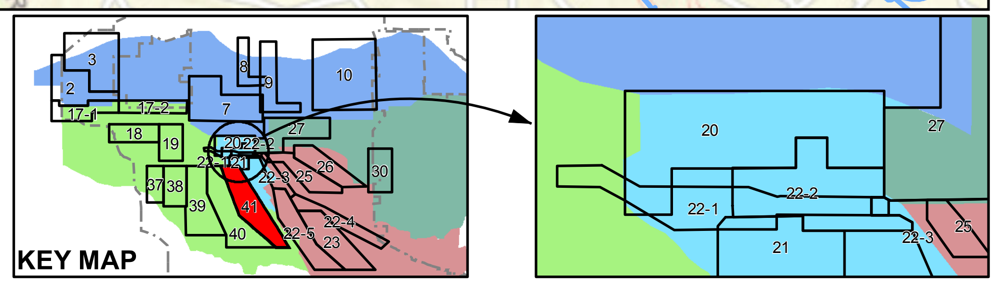
FIGURE 3-7H



5/13/2014 JN M:\Mdata\136769\GIS\MXD\136769_Proposed_Facilities.mxd KCHAN

LEGEND

- *36"* Proposed Main Line Sizes
- *(36")* Existing Main Line Sizes
- RCC Rectangular Concrete Channel (W'xH')
- NC Natural Channel (W'xH')
- **2A** Storm Drain Facility ID
- Proposed Storm Drain Facility
- Existing Storm Drain Facility
- Storm Drain Facilities Shown Elsewhere
- City Boundary
- Exhibit Focus Area
- Mission Zanja
- Reservoir Canyon
- Downtown
- North City
- South City



RBF CONSULTING
A Baker Company

0 1,875 3,750 Feet

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE
WATERSHED: SOUTH CITY

MAIN STORM DRAIN FACILITIES - PROJECT AREA 41

FIGURE 3-7I

3.5.4 Cost Estimates

For each system, RBF has provided a recommendation for proposed storm drain facility replacement.

Table 3-16 gives a summary of the construction cost estimates and the recommended system within the South City area. See Appendix C for detailed cost estimates.

Table 3-16: South City Drainage Area Cost Estimate Summary

System No.	Recommended System Diameter (inches)	Total Project Cost (2014 $)
17-B	30	$69,000
	36	$196,000
17-A	48	$463,000
	60	$671,000
	66	$38,000
	72	$1,547,000
	84	$104,000
	108	$1,508,000
18	42	$193,000
	48	$213,000
	10'w x 3'h RCB	$1,597,000
18-A	36	$62,000
	42	$159,000
19	60	$250,000
	72	$1,134,000
38	30	$12,000
	60	$615,000
	66	$200,000
38-B	60	$612,000
39	48	$526,000
	54	$488,000
	60	$76,000
39-A	42	$205,000
	48	$703,000

System No.	Recommended System Diameter (inches)	Total Project Cost (2014 $)
	54	$682,000
39-C	30	$77,000
	36	$89,000
	42	$175,000
40	66	$247,000
	72	$936,000
	14’w x 5’h RCC	$419,000
	10’w x 7’h RCB	$478,000
41	4’w x 2’hRCC	$475,000
	4’w x 3’h RCC	$446,000
	4’w x 3’h RCC	$446,000
	5’w x 3’h RCC	$801,000
	7’w x 3’h RCC	$470,000
	8’w x 4’h RCC	$691,000
Total System Cost		**$18,075,000**

ENR Construction Cost Index = 9750 (April 2014)

4 Capital Improvement Plan

A priority ranking has been developed based on levels of system deficiencies per Section 2.3. The goal of the priority ranking system is to determine the projects of the greatest importance and determine which projects should be constructed first when funding becomes available. Note that in situations where portions within a pipe segment consisted of multiple priorities, the ultimate priority assigned to a particular segment defaulted to the highest priority on that segment. Detailed calculations can be found in Appendix D.

Table 4-1 through 4-4 provide cost summaries of the four priorities respectively. More detailed information for the proposed facilities and priorities are included in Figures contained in Section 3 above.

Table 4-1: Priority 1a Cost Estimate Summary

Watershed	Proposed Cost
Mission Zanja	*$15,920,000*
Reservoir Canyon	*$3,393,000*
Downtown	*$10,210,000*
South City	*$5,980,000*
North City	*$4,690,000*
Total Priority 1a System Cost	***$40,190,000***

ENR Construction Cost Index = 9750 (April 2014)

Table 4-2: Priority 1b Cost Estimate Summary

Watershed	Proposed Cost
Mission Zanja	*$2,820,000*
Reservoir Canyon	*$13,110,000*
Downtown	*$0*
South City	*$0*
North City	*$14,780,000*
Total Priority 1b System Cost	***$30,710,000***

Table 4-3: Priority 2 Cost Estimate Summary

Watershed	Proposed Cost
Mission Zanja	*$0*
Reservoir Canyon	*$0*
Downtown	*$0*
South City	*$2,530,000*
North City	*$0*
Total Priority 2 System Cost	***$2,530,000***

Table 4-4: Priority 3 Cost Estimate Summary

Watershed	Proposed Cost
Mission Zanja	*$0*
Reservoir Canyon	*$0*
Downtown	*$0*
South City	*$9,570,000*
North City	*$590,000*
Total Priority 3 System Cost	***$10,150,000***

5 Green Initiatives

As part of this Master Plan of Drainage, water quality and water replenishment initiatives were evaluated. In accordance with the requirements of the Santa Ana RWQCB Permit No. R8-2010-0036, the City is to establish a review, approval and permitting process for new development and redevelopment occurring within its boundaries.

This MPD includes potential applications for redevelopment and retrofitting existing drainage facilities to accommodate water quality treatment and/or groundwater replenishment. Ten (10) locations have been identified for "Green Initiatives" based on location, soil type, land use, and tributary drainage area size.

Water quality facilities are designed to treat the "first flush", or the smaller more frequent rainfall events. However, water quality facilities are not capable of treating or handing large flow events. The inherent design of the water quality facility, and the storm event that it treats, requires that the first flush volume is captured. Therefore when the larger volume of storm runoff arrives from the large return frequency storms (i.e. 10-year or larger), the water quality feature is already full, and further attenuation of the peak storm is infeasible. Some volume based best management practices (BMPs) are capable of treating larger area, such as extended detention basins, retention basin, or large wetlands. Yet even these facilities cannot treat larger storm events. Combined flood control detention basins can be designed to treat water quality as well, but the treatment mechanism in the water quality portion of the basins will only treat the "first flush" storm events.

Low impact development (LID) strategies are encouraged in the NPDES Permit. The idea of disconnecting impervious surfaces leads to "first flush" or small storm partial infiltration. This could be beneficial for new development or redevelopment with respect to slowing the local drainage "Time of Concentration" to produce lower peak flows during small storm events. With respect to large storm events, generally over 2-year storm events, these "impervious" areas or water quality features are not designed to accept the flows.

A comprehensive study of the City's drainage areas has been performed to identify potential areas for Green Initiatives, or combined water quality/ground water recharge facilities. To maximize the facility benefits, large open space areas (for facility footprint) with a sizable drainage tributary area were evaluated. In some cases, smaller areas were also considered based on land use and potential to treat large paved or impervious areas.

The ten sites identified in this study are shown in Figure 5-1. A summary of each site is given in Table 5-1.

Table 5-1: Green Initiative Sites Summary

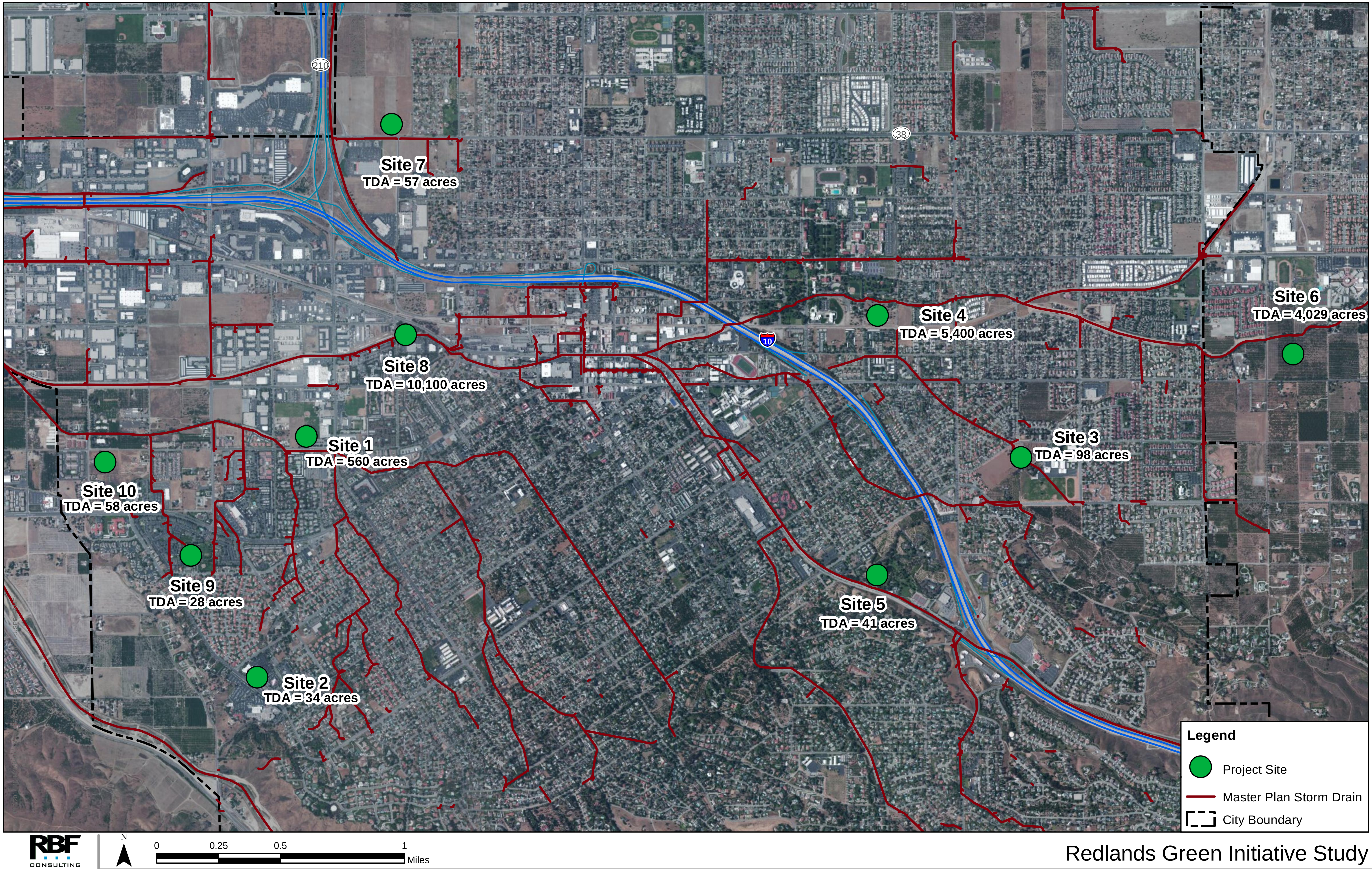
Site	Drainage Area (acres)	Recommended Facility (BMP)	Notes
1	560	Infiltration Basin/Underground Storage	Two potential sites adjacent to each other.
2	34	Bioretention	Treatment of existing parking lot.
3	98	Infiltration Basin	Located in existing drainage area.
4	5,400	Infiltration Basin	Site tentatively accepted by University of Redlands.
5	41	Infiltration Basin/Underground Storage	Site adjacent to Reservoir Canyon storm drain.
6	4,030	Infiltration Basin	Future planned Opal Basin
7	57	Underground Infiltration/Bioretention	Future Walmart site.
8	10,100	Infiltration Basin	Jenny Davis Park adjacent to channel.
9	28	Infiltration Basin	Existing park site with large potential site area.
10	58	Infiltration Basin	Located in existing drainage area.

These Green Initiatives have been identified as some of the best potential locations for effective ground water recharge. Further evaluation of these sites would include detailed geotechnical investigations, property owner coordination, and land use evaluation. Proper installation, operation, and maintenance of these types of facilities are paramount to their effectiveness and longevity. Although these sites have been identified as the best suitable locations for “green” infrastructure, the facilities identified as part of the MPD flood control plan can be further evaluated for potential “green” infrastructure during the design phase.

The MPD identifies the required conduit necessary to minimize flooding potential for the given design storm events. These facilities could be potentially replaced with “greener” facilities. Some of these facilities can be seen below:

- Earthen or soft bottom channels,
- Arch structures with earthen inverts,
- Use of vegetated strips and/or swales in lieu of curb and gutter,
- Perforated or slotted pipe/box/closed conduit,
- Articulated block channels,

Each of these “green” elements has design restrictions, depending on the particular use and site characteristics. The presence of high velocity flows and cost are the most deterministic characteristics in the design feasibility of these types of facilities. During the design phase of any proposed storm drain, these alternative types of facilities should be considered based on the site constraints. For a detailed evaluation of each site, refer to Appendix E.



RBF CONSULTING A Baker Company

Redlands Green Initiative Study

Source: Esri, USGS, San Bernardino County Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5-1

6 Available Drainage Data/Material

As part of the Master Plan of Drainage project, RBF has acquired the available data provided by the City to be used as part of the Master Plan of Drainage. These include:

a) Available Drainage As-Built Plans
b) Drainage Reports
c) FEMA Flood Insurance Rate maps
d) 2014 City Topographic data
e) 2013 County Topographic data
f) 2013 City Aerial Imagery

6.1 Drainage As-Built Plans

RBF Reviewed the As-built plans provided by the City and sorted out those that do not reflect the existing conditions within the City of Redlands. Some of the plans provided appeared to have been superseded by recent improvements. During this review, it was noted that the available as-built plans do not cover most of the storm drain mainlines and laterals shown on the City's storm drain base file provided by the City.

The City GIS storm drain data was updated based on the information researched in this MPD. Some of the aspects of the GIS data that were updated due to missing or incorrect input included the following:

- Storm drain sizes;
- Storm drain types (i.e. RCB instead of RCP);
- Addition of storm drain, and;
- As-built linkages.

The updated GIS database has been included as part of this MPD effort.

7 Final Considerations and Future Recommendations

Master Plan of Drainage studies are planning level documents focused on identifying a city-wide storm drainage system to alleviate flooding to an acceptable limit. Implementation of any facility identified in this document will be supplemented with detailed hydrology and hydraulic calculations during the final design process. Some of the detailed information that would be performed during final design would include detailed geotechnical investigations, utility location, and AMC III hydrology calculations (for regional facilities).

For the Regional Alternatives analyses, in the Downtown area, two alternatives were evaluated for the long term flooding issues affecting the area. Three large tributaries route flows to the existing Redlands Boulevard storm drain, where they confluence around 9th Street. The two largest tributaries include the Mission Zanja and Reservoir Canyon storm drains, with a moderately large tributary from the Oriental storm drain.

Our hydraulic analyses suggest that all three of these systems contribute significantly to the current flooding conditions in the downtown area. The two Regional Alternatives identified in this study include large systems that would need to be implemented to alleviate the flooding. Both systems have their own constructability issues.

Alternative 1 includes the addition of a large culvert adjacent to the existing Redlands Boulevard storm drain. This could incur difficulties with underground utilities and access to businesses along the main transportation corridor within the City.

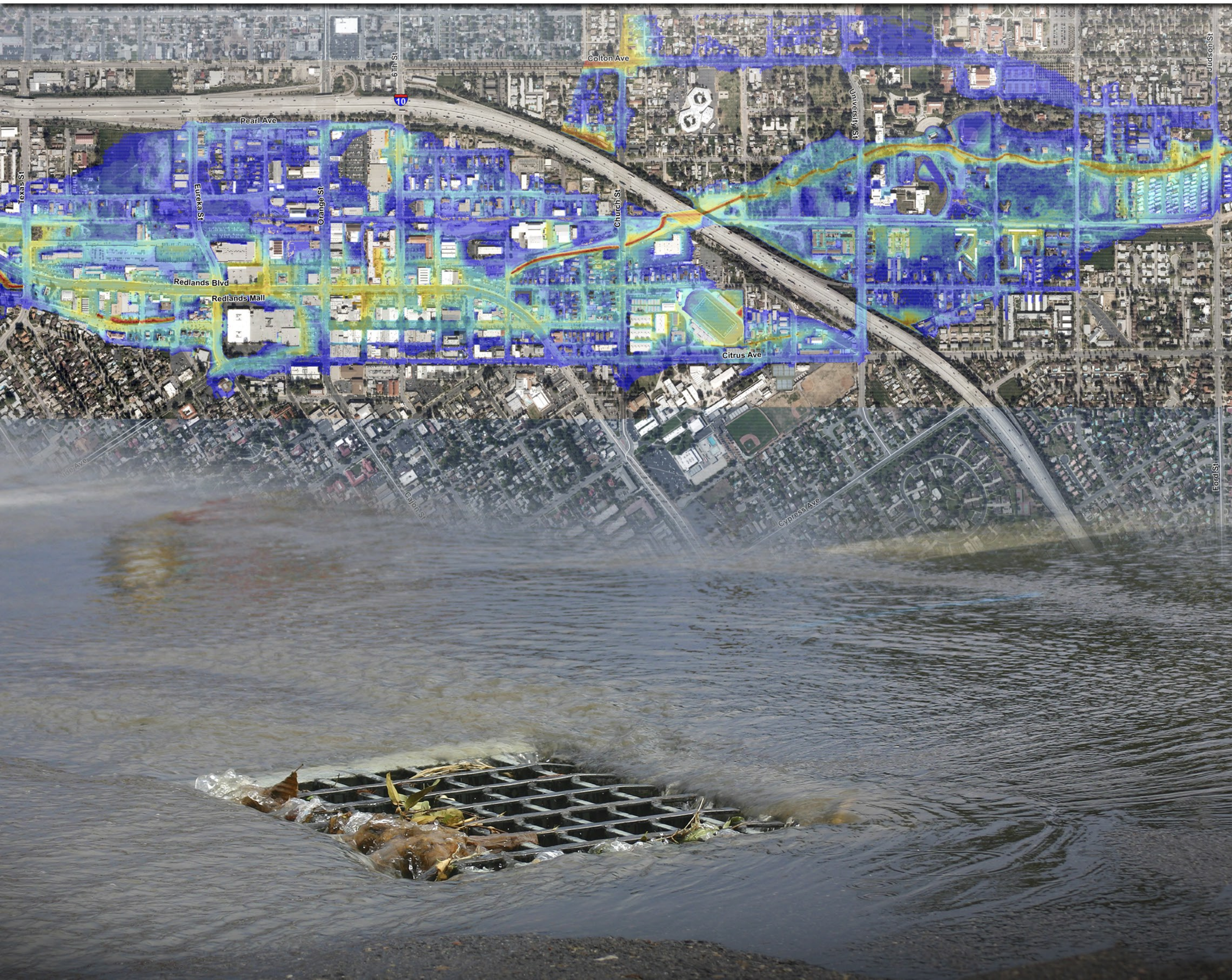
Alternative 2 includes a bypass structure that would direct the Zanja through the current City easement. A secondary connection is proposed from the Redlands Boulevard storm drain at 9th Street to the proposed Zanja bypass to accommodate some of the Reservoir Canyon peak flows. A third regional improvement to the existing Redlands Boulevard storm drain would need to be implemented along West State Street to Texas Street. The main issue with this alternative is the limited right-of-way for the Zanja bypass system. Hydraulically, a double 12-foot wide by 8-foot high reinforced concrete box is required to adequately alleviate the flooding in the downtown area. To construct a box of this size, a minimum right-of-way of approximately 45 feet would be needed. The existing storm drain easement for most of the proposed alignment is 20 feet. In some locations along this proposed bypass alignment, only 20 feet exists between existing structures. For this reason, Alternative 2 was deemed infeasible. Further studies could be performed for this alternative to include several bypass systems, but based on our evaluations, none were determined feasible.

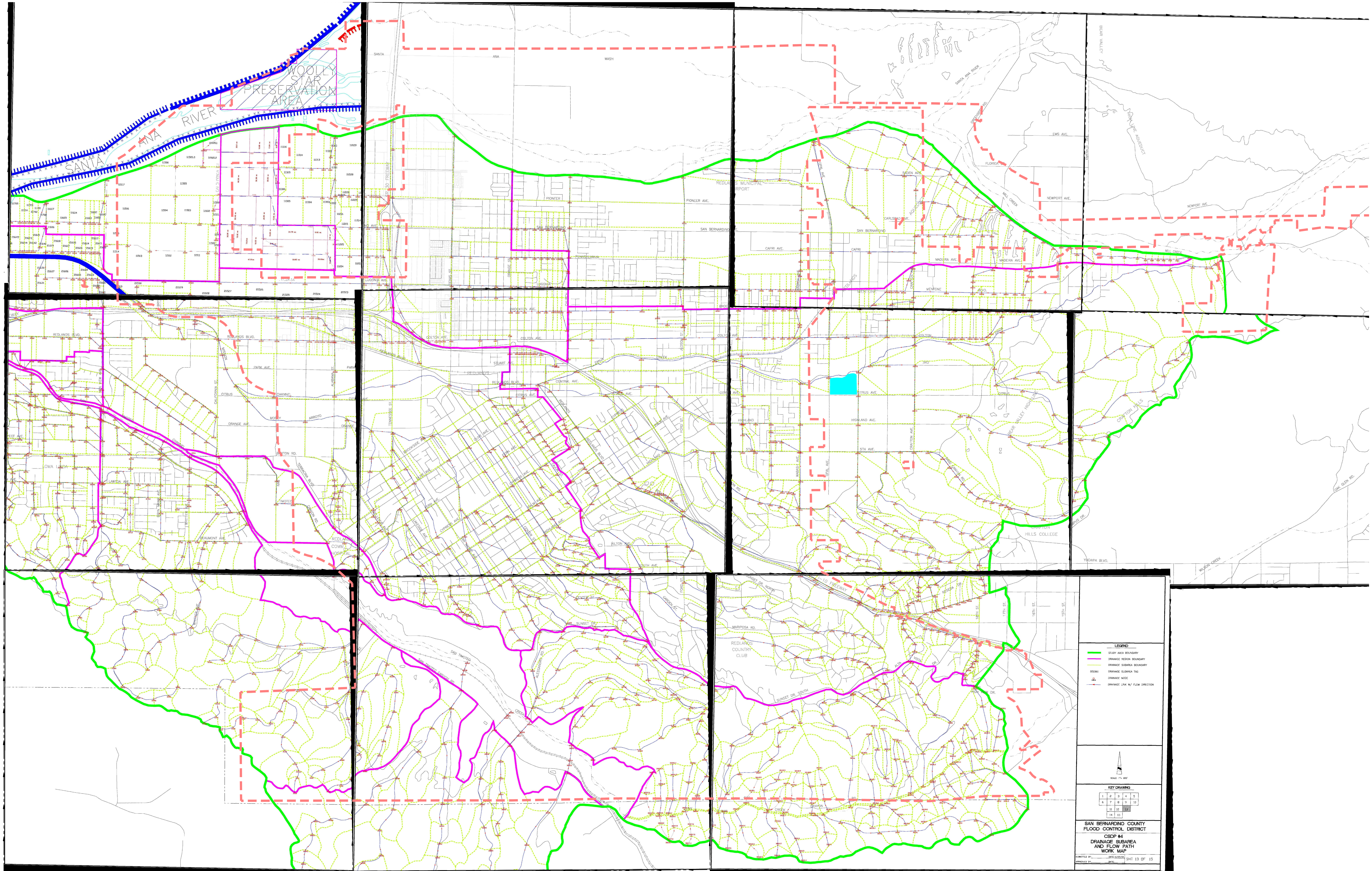
The Oriental storm drain contributes approximately 1,000 acres of tributary drainage area to the Reservoir Canyon storm drain just north of Citrus Avenue, with a 100-year peak flow of about 1,300 cfs. This system is part of the Reservoir Canyon Watershed plan and is proposed to be upsized with a bypass included. The bypass would route some of the flows down Citrus Avenue. During final design of this system, more detailed calculations will be performed to identify potential alternative alignments for this structure.

The proposed Opal basin was evaluated based on the currently available grading plans provided by the City. RBF performed hydrologic routing calculation based on the concept grading plan and assumed six to seven feet of freeboard for the AMC II, 100-year storm event. When the final design is complete, design level hydrology will produce an AMC II outflow hydrograph that will supersede this MPD results. If they peak basin outflow varies from the estimated MPD outflow, a regional model should be evaluated to understand the impacts on the downtown area.


RBF CONSULTING
A Baker Company

14725 Alton Parkway, Irvine, CA 92618
949.472.3505
www.rbf.com | www.mbakercorp.com





SCALE: 1"=1600'

1600 800 0 1600 3200 4800

SCALE: 1"=1600'

RBF CONSULTING

A Baker Company

Legend

City Boundary

Opal Basin

EXHIBIT 1

EXISTING HYDROLOGY MAP

CITY OF REDLANDS

MASTER PLAN OF DRAINAGE

5/15/2014 JN M:\Mdata\136769\GIS\MXD\Exhibit3 SD Facilities Identification Map24x36.mxd KCHAN

RBF CONSULTING A Baker Company

0 0.25 0.5 1 Miles

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

MAIN STORM DRAIN FACILITIES IDENTIFICATION MAP

Exhibit 3

RBF CONSULTING

0 0.25 0.5 1 Miles

Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

MAIN STORM DRAIN FACILITIES - PROPOSED PRIORITIES

Exhibit 4