Solvang Stormwater System Master Plan

City of Solvang
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Solvang, CA 93463

TETRA TECH

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June 28, 2019

PRESENTED TO

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EXECUTIVE SUMMARY

As the City of Solvang (City) undergoes further development and urbanization, there is a need to evaluate the existing storm drain infrastructure capacity and identify the necessary recommendations to respond to growth as a way to provide long-term resiliency. This Stormwater System Master Plan (SSMP) has been developed to evaluate existing system capacity to ensure the storm drain network is able to meet its intended level of service and aid the City's capital improvement program (CIP) development. Specifically, the SSMP was strategically developed to meet several objectives:

- Leverage the existing storm drain inventory to generate a ***fully articulated stormwater model***,
- Define ***clear flood control performance criteria*** for which stormwater infrastructure could be assessed,
- Utilize an ***advanced, high-resolution urban stormwater model*** (PCSWMM),
- Support the identification and characterization of ***innovative site-specific improvements that can provide integrated flood control, water quality, and development benefits***, and
- Prioritize identified projects to inform ***meaningful CIP and implementation***.

High resolution data and powerful analytical tools allowed for the assessment of the existing condition to the inlet scale, subsequently highlighting discrete flooding concerns throughout the City. An iterative and site-specific approach was taken to identify potential improvements at each flooding location. The methodology leveraged an innovative approach that went beyond the grey-infrastructure approach, which is the focus of traditional stormwater plans. Rather, opportunities for integrated projects with green infrastructure components were identified to align with potential grant opportunities and preemptively prepare for future water quality regulations. Following an iterative refinement process of opportunities based on City preferences, final recommendations were determined for each flooding location. These recommendations include ***0.80 miles of conduit improvements*** (0.33 miles new, 0.47 miles upsized), ***240 feet of culvert improvements*** (all upsized), ***11 inlet improvements*** (3 new and 8 upsized), and ***0.5 acre-feet of new distributed detention*** (e.g., suspended vaults).

Capital costs were determined for all proposed improvements, which included material costs, construction costs, planning and design costs, permitting, construction management, mobilization, and a mark-up for contingency. The total estimated cost of all recommended improvements was estimated at ***$4.4 million dollars.*** In acknowledgement that the improvements will need to be constructed over time, a prioritization framework was created through collaboration with the City to direct CIP efforts. Prioritization was driven by the calculated business risk exposure (BRE) for each of the project groups, which identifies the probability and consequence of failure (i.e., flooding) at each location. Projects mitigating for higher flood risk were prioritized, with additional consideration given to improvements that addressed asset deterioration, **trash capture device implementation**, permitting issues, burden of maintenance, and future development.

Courtesy: City of Solvang

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
1D	One-dimensional
2D	Two-dimensional
ac	Acre
ac-ft	acre-feet
ASCE	American Society of Civil Engineers
BMP	Best management practice
CEQA	California Environmental Quality Act
CCRWQCB	Central Coast Regional Water Quality Control Board
cf	cubic feet
cfs	cubic feet per second
CIP	Capital improvement plan
CIPCP	Cast in place concrete pipe
CMP	Corrugated metal pipe
COF	Consequence of failure
DEM	Digital elevation model
EMC	event mean concentration
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GIS	Geographic information system
H&H	Hydrologic and hydraulic
hr	Hour
HSG	Hydrologic soil group
in	Inches
IRWMP	Integrated Regional Watershed Management Plan
L	Liter
LID	Low impact development
LiDAR	light detection and ranging
LPR	Load prioritization reduction
MS4	Municipal Separate Storm Sewer Systems
NDVI	Normalized difference vegetation index
NEPA	National Environmental Protection Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System

Acronyms/Abbreviations	Definition
NRCS	National Resources Conservation Service
ODOT	Oregon Department of Transportation
PCSWMM	Personal Computer Storm Water Management Model
PEAIP	Program Effectiveness Assessment and Improvement Plan
POF	Probability of failure
RCP	Reinforced concrete pipe
ROW	Right-of-way
SBFCD	Santa Barbara Flood Control and Water Conservation District
SBPAT	Structural BMP Prioritization Tool
sf	square feet
SSMP	Stormwater System Master Plan
SWMP	Solvang Storm Water Management Plan
SWRCB	State Water Resources Control Board
TKN	Total kjeldahl nitrogen
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WDR	Waste Discharge Requirements
WSE	Water surface elevation

1.0 INTRODUCTION

The City of Solvang (City) is a 2.5 square mile, moderately urbanized jurisdiction within Santa Barbara County (County) as shown in Figure 1-1, which is drained by eight separate watershed basins, all of which ultimately flow to the Santa Ynez River. The City is subject to numerous stormwater management requirements and design standards with regards to flood control and water quality, necessitating a comprehensive evaluation of the current stormwater system. An assessment of current conditions and proposed improvement solutions is needed to develop a strategic and cost-effective plan for stormwater system improvements and water quality management. This information must be placed into the context of local stormwater regulations and management standards so that the City ensures they are meeting both current and anticipated regulatory requirements and providing the required level of service through their existing stormwater system. This Stormwater System Master Plan (SSMP) lays out what the City needs to do to accomplish these goals and provides a guide for future planning and management efforts. This is the first comprehensive drainage plan for the City and the contents will set the direction for the City's future stormwater management efforts that come in the context of dynamic climate and regulatory environments. The comprehensive nature of the SSMP will provide a robust foundation to address current needs and to adapt to those that may arise in the future. The SSMP identifies key opportunities for integrated projects and potential grant opportunities and provides an integrated plan to provide flood management.

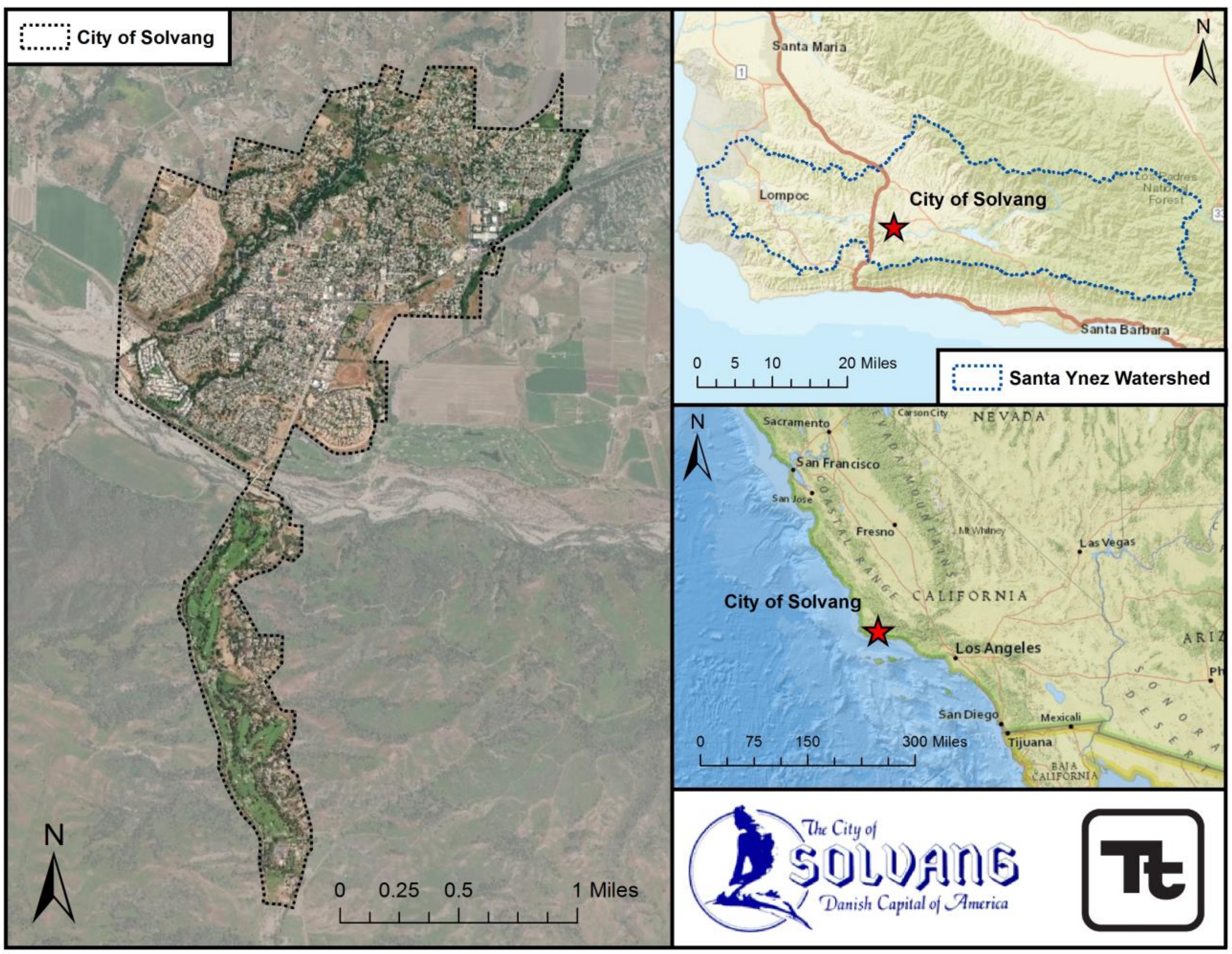

Figure 1-1. City of Solvang location context

Pursuant to the goals of the SSMP, a fully articulated stormwater model was developed using the most comprehensive City and regional datasets. The data was applied to determine the existing condition for the City's drainage system and to support the identification and characterization of system-specific recommendations where the required level of service is not currently provided. Modeling allows the investigation of the drainage system response to simulated flooding events by utilizing an advanced, high-resolution urban stormwater model with spatially-explicit representation of City runoff and drainage patterns as they exist for larger storms. To fully assess the City's drainage system, a City-wide hydrologic and hydraulic (H&H) analysis was performed. Hydrologic assessment provided accurate quantification of runoff and peak flow rates from selected design storms for surface flow capacity analysis. Surface flows were then routed along the existing stormwater conveyance system where hydraulic analysis provided an assessment of the existing system's ability to convey flood-event runoff. Results from this model indicated where deficiencies in the stormwater conveyance may exist and the degree of magnitude of the associated flooding. Using these results, appropriately placed and sized improvements can be made to ensure the required level of service moving forward.

The following sections of this report detail the development and analysis of this modeling approach used to identify system deficiencies and provide recommendations covering the following topics:

- Regulatory Guidance (Section 2)
- Data Collection & Model Inputs (Section 3)
- Model Methodology (Section 4)
- Existing Conditions Modeling Detail (Section 5)
- Proposed Improvements (Section 6)

Modeling details are followed by a prioritization framework (Section 7) that the City can use to ensure they pursue the proposed recommendations commensurate to the risk they pose to City infrastructure given future flood events. The results of this prioritization framework applied to the proposed improvements (Section 8) demonstrates which projects address the greatest risk to City infrastructure. The prioritization framework also takes into consideration project costs to make a clear roadmap for the City to pursue these improvements with clear guidance. Finally, future recommendations (Section 9) serve to provide the City with guidance and considerations for carrying out these improvements and manage the stormwater system moving forward.

2.0 REGULATORY GUIDANCE

To ensure this drainage plan meets the applicable guidance for drainage, as well as water quality requirements as it relates to integrated projects within the City, a comprehensive data review of regulatory requirements, design guidance, and previous/ongoing studies was conducted. These documents provide a foundation for the stormwater targets that were used to assess the existing condition of the Solvang stormwater system.

2.1 FLOOD CONTROL GUIDANCE

To assess the level of service provided by the existing stormwater system, local guidelines and statewide guidelines were referenced to establish performance criteria and assess potential deficiencies. These standards served as the basis for a structured pathway to propose improvements to the City's stormwater assets.

2.1.1 County of Santa Barbara Hydrology Report

The County of Santa Barbara Hydrology Report (Santa Barbara County 2016) documented recent trends in rainfall, groundwater levels, stream flow, flooding, and burn areas across Santa Barbara County for Water Year 2016. The Hydrology Report was reviewed for information regarding regional hydrological monitoring and reporting to provide background and context for climate and hydrologic conditions that the City of Solvang experiences. This Master Plan refers to the rainfall gages and stream gages identified in the County report in assessing flooding probabilities and levels.

2.1.2 City of Solvang Stormwater Management Program

The City of Solvang Storm Water Management Program (SWMP) (City of Solvang 2010) lays out the City's plan to comply with the General Permit for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems (MS4s). The SWMP defines the City's objective of reducing the discharge of pollutants to protect water quality and lays out certain strategies that the City will take to do so. The SWMP documented the six control measures that will be part of the City's process towards General Permit compliance, which included (1) Public Education and Outreach; (2) Public Involvement and Participation; (3) Illicit Discharge Detection and Elimination; (4) Construction Site Stormwater Runoff Control; (5) Post-Construction Stormwater Management in New Development; and (6) Pollution Prevention/Good Housekeeping for Municipal Operations. The SWMP addresses these measures and provides a suite of City-approved structural Best Management Practices (BMPs) to reduce pollutant loading to receiving waters, a recommended post-construction stormwater maximum discharge rate, and a geospatial format for proposed CIP project information that can be added to the City's geographic information system (GIS) portal to enhance public interaction and involvement with City management activities.

2.1.3 Santa Barbara County Flood Control and Water Conservation District Standard Conditions of Project Plan Approval

The Santa Barbara County Flood Control and Water Conservation District (SBFCD) Standard Conditions of Project Plan Approval (SBFCD 2010) provides guidelines for flood control design parameters, including rainfall depths and intensity and the preferred source for local soil information. This report identifies flood control criteria to assess the level of service provided by existing storm drain system and assess potential deficiencies. The County's flood control criteria are summarized in Table 2-1 below. The Project Plan Approval document also establishes standards for several flood control measures and stormwater conveyance infrastructure. Flood control improvement measures are discussed in detail in Section 6.3. The County report also includes post-development peak stormwater runoff discharge rates.

Table 2-1. New Development Project Flood Control Criteria

Category	Criteria	Source
Maximum Gutter Flow	10-year, 24-hour storm, 10 cfs	SBFCD 2010
Total Street Flow Depth	25-year, 24-hour storm, ≤ curb height	SBFCD 2010
Total Street Flow Depth at Arterial, Major, and Industrial Streets	10- & 25-yr, 24-hour storm – One lane dry in each direction 100-yr, 24-hour storm – within ROW or private street easement	SBFCD 2010

2.1.4 Post-Construction Stormwater Management Requirements for Development Projects in the Central Coast

In addition to development requirements laid out in the SBFCD Standard Conditions of Project Plan Approval document, the Post Construction Stormwater Management Requirements for Development Projects in the Central Coast Region User Guide for Municipal Implementation (SWRCB 2013) has several impervious area specific post-construction requirements. Santa Barbara County Water Resources Division (SBC WRD) Stormwater Technical Guide for Low Impact Development (Santa Barbara County 2017) also details post-construction requirements for stormwater management. Requirements from both guidance documents are listed in Table 2-2. It is recommended that the City adopt the stricter of the two guidelines to determine discharge rate requirements for new and redevelopment projects.

2.1.5 Phase II Small MS4 Permit

The National Pollutant Discharge Elimination System (NPDES) General Permit for Waste Discharge Requirements (WDRs) for Stormwater Discharges from Small MS4s (SWRCB 2013) details the requirements for Permittees of municipal stormwater discharges. The MS4 permit dictates Permittee requirements of Public Outreach, Education and Involvement in a stormwater program, required maintenance, monitoring, and sampling of stormwater discharge within the jurisdiction, and effluent and receiving water constituent levels. As proposed improvements are enacted, attention to these requirements is important to ensure all regulatory requirements for the stormwater permit are met.

Table 2-2. New or Re-development Runoff Requirements

Flood Control Infrastructure	Requirement	Source
New/Redevelopment ≥ 2,500 sf entire project area	Implement at least one of the runoff reduction measures	SWRCB 2013
New/Redevelopment ≥ 5,000 sf net impervious area	LID to retain runoff volume of 85% storm	SWRCB 2013
New/Redevelopment ≥ 15,000 sf net impervious area	Prevent discharge of the 95% or 85% 24-hr event depending on flood control measure selected	SWRCB 2013
New development ≥ 22,500 sf net impervious area Redevelopment ≥ 22,500 sf in which additional runoff is generated by increased impervious area	Post-project peak flows shall not exceed pre-project peak flows for the 2-yr through 100-yr Storm Events	SWRCB 2013
New/Redevelopment projects, including single-family homes that are not part of a larger plan of development (SFHs), that create/replace ≥2,500 sf of impervious area (Tier 1)	Limit disturbance of natural drainage features; Limit clearing, grading, and soil compaction; Minimize impervious surface; Minimize runoff by dispersing runoff to landscape or using permeable pavement	SBC WRD 2017
New/Redevelopment projects, other than SFHs, that create/replace ≥ 5,000 sf net impervious area (Tier 2)	Tier 1 requirement, plus: Treat runoff with an approved and appropriately sized LID treatment system prior to discharge from the site	SBC WRD 2017
New/Redevelopment projects, other than SFHs, that create/replace ≥ 15,000 sf of impervious area. SFHs that create/replace ≥ 15,000 sf net impervious area (Tier 3)	Tier 2 requirements, plus: Prevent offsite discharge from events up to the 95th percentile rainfall event using Stormwater control Measures	SBC WRD 2017
New/Redevelopment projects that create/replace 22,500 sf impervious area (Tier 4)	Tier 3 requirements, plus: Control peak flows to not exceed pre-project flows for the 2-yr through 10-yr events.	SBC WRD 2017

2.2 WATER QUALITY GUIDANCE

Local and State water quality objectives were reviewed and compiled to create a comprehensive assessment framework for existing stormwater runoff characterization. In addition to flood control objectives, the City has stated that prioritization of CIP projects shall include a thorough ranking system incorporating flood control and water quality objectives. The following sections review local water quality guidelines and regulations related to the waterbodies described herein and that discharge from the City of Solvang.

2.2.1 Santa Barbara County Integrated Regional Water Management Plan

The Santa Barbara County Integrated Regional Water Management Plan (IRWMP) (Santa Barbara County 2013) is a County-wide regional water management planning document. The IRWMP documents the various existing water treatment and flood control facilities, groundwater reports, and various water quality objectives based on beneficial uses. These are important to consider if green infrastructure improvements are pursued as these offer multiple benefits for both flood protection and water quality for the watershed.

2.2.2 Statewide Trash Provisions for Small MS4 Permittees

The Statewide Trash Provisions for Small MS4 Permittees (SWRCB 2017) provides guidelines for Permittees to comply with the statewide trash capture mandates. This requires that jurisdictions assess existing levels of trash generation and create an implementation plan to introduce trash control and demonstrate how they will achieve Full Capture System Equivalency. These requirements have the potential to be addressed with certain proposed improvement types (e.g., inlet replacement) by designing projects with multiple benefits keeping trash capture regulations in mind.

2.2.3 Scoping Report of Total Maximum Daily Loads Addressing Nutrient Pollution in Streams of the Santa Ynez River Basin

This document presents information to support the development of total maximum daily loads (TMDLs) for nutrients in streams of the Santa Ynez River basin. The Scoping Report (CCRWQCB 2016) also identified the various beneficial uses for the downstream Santa Ynez River, which runs through the southern portion of the City. The waterbody beneficial uses dictate the suite and degree of water quality objectives for each waterbody. The Santa Ynez River is currently designated for all beneficial uses indicating it is a well-protected natural waterbody. These beneficial uses span municipal, domestic, and commercial water supply, recreation with contact, and habitat designations for a range of species and conditions supporting healthy ecosystems.

2.2.4 CEQA/NEPA

The California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) define the procedures for environmental review and impact analyses of projects that require approval by local or state agencies and federal agencies, respectively. A public agency must comply with the environmental acts for projects that may cause either direct physical change or possible indirect change to the environment (AEP 2019). These requirements include not only natural resource protection but also historical and anthropologic provisions that safeguard against changes to cultural resources as well. While these requirements are not required at early phases of planning and design, they are necessary before construction and should be acknowledged for projects that include any proposed changes to local water bodies.

2.3 LOW IMPACT DEVELOPMENT GUIDANCE

Additional regional documents were referenced to compile applicable design guidance for Low Impact Development (LID) projects. LID projects or green infrastructure are attractive alternatives to traditional hard infrastructure because of the multiple benefits they offer. Well-designed green infrastructure provides the multiple benefits of both stormwater volume capture for flood protection as well as filtration and removal of pollutants for water quality. The sections below give a brief review of the sources and how they were applied to guide project design.

2.3.1 Santa Barbara County Stormwater Technical Guide for Low Impact Development

The Santa Barbara County Stormwater Technical Guide for Low Impact Development (Santa Barbara County, 2017) covers the design and documentation for LID compliance with the Post-Construction Requirements. The document covers the design calculations and specifications for new or re-development areas planning to self-treat or self-retain runoff. The Technical Guide provides resources to estimate infiltration rates and plans for bioretention and porous pavement projects.

2.3.2 Program Effectiveness Assessment and Improvement Plan Load, Prioritization, Reduction (LPR) Model Guidance Document

The Program Effectiveness Assessment and Improvement Plan (PEAIP) Load, Prioritization, Reduction (LPR) Model Guidance Document (Geosyntec 2015) follows the process for quantifying the runoff volume and pollutant loads within Santa Barbara County jurisdictional MS4 Permit areas. The model can be used by the County and jurisdictions within the County to quantify baseline runoff volumes and pollutant loads, identify priority catchments for stormwater BMP implementation, and to estimate load reductions resulting from the PEAIPs. The LPR model applied local land use-specific event mean concentration (EMC) values.

3.0 DATA COLLECTION & MODEL INPUTS

To build out the full drainage system model for the City, quality input data is needed to ensure that modeling results are as accurate as they can be. Accurate modeling results help ensure that any flooding identified in the simulated results closely represents what would happen given a similar storm event occurring in the City. A large amount of data is needed to build a full H&H model, and this data was collected from established geospatial datasets received from the City. Where additional data was needed, it was supplemented with local and regional sources consistent with guidance documents and other modeling standards. The following subsections detail the input data and highlight why each is important to the final modeling results.

3.1 WATERSHED AND DRAINAGE AREAS

Solvang is located within the Santa Ynez River watershed, which encompasses approximately 897 square miles and 363 sub-basins (Figure 3-1). The City is a 2.43 square-mile municipality located in southwest Santa Barbara County. The City is bounded by Adobe Canyon Creek to the west, Alamo Pintado Creek to the east, and Alisal Creek in the south, with the Santa Ynez River bisecting the City just south of Alisal Road and Fjord Drive. Solvang's climate is semi-arid/Mediterranean (sunny, dry, and cool with damp evenings), with an average annual precipitation of 19 inches that falls predominantly in winter months. The greater watershed position and climate setting serve to validate modeling boundary conditions and climate data used to simulate design storms.

Figure 3-1. Modeled Solvang Drainage Area in Santa Ynez Watershed

3.2 STORM DRAIN NETWORK

Pursuant to the SSMP development, the City provided a georeferenced storm drain infrastructure dataset comprised of conveyance lines and structures (Figure 3-2). The conveyances layers included linear assets and associated conduit attributes, including: location, direction, length, size, material, and ownership of many of the existing conduits and culverts. The structures layer included nodal data for each asset, including the infrastructure type (e.g., catch basin, inlet, cleanout, and junction, etc.), location, ID, ownership, and size. The following subsection summarizes the received storm drain data and assesses it for completeness for developing an H&H model.

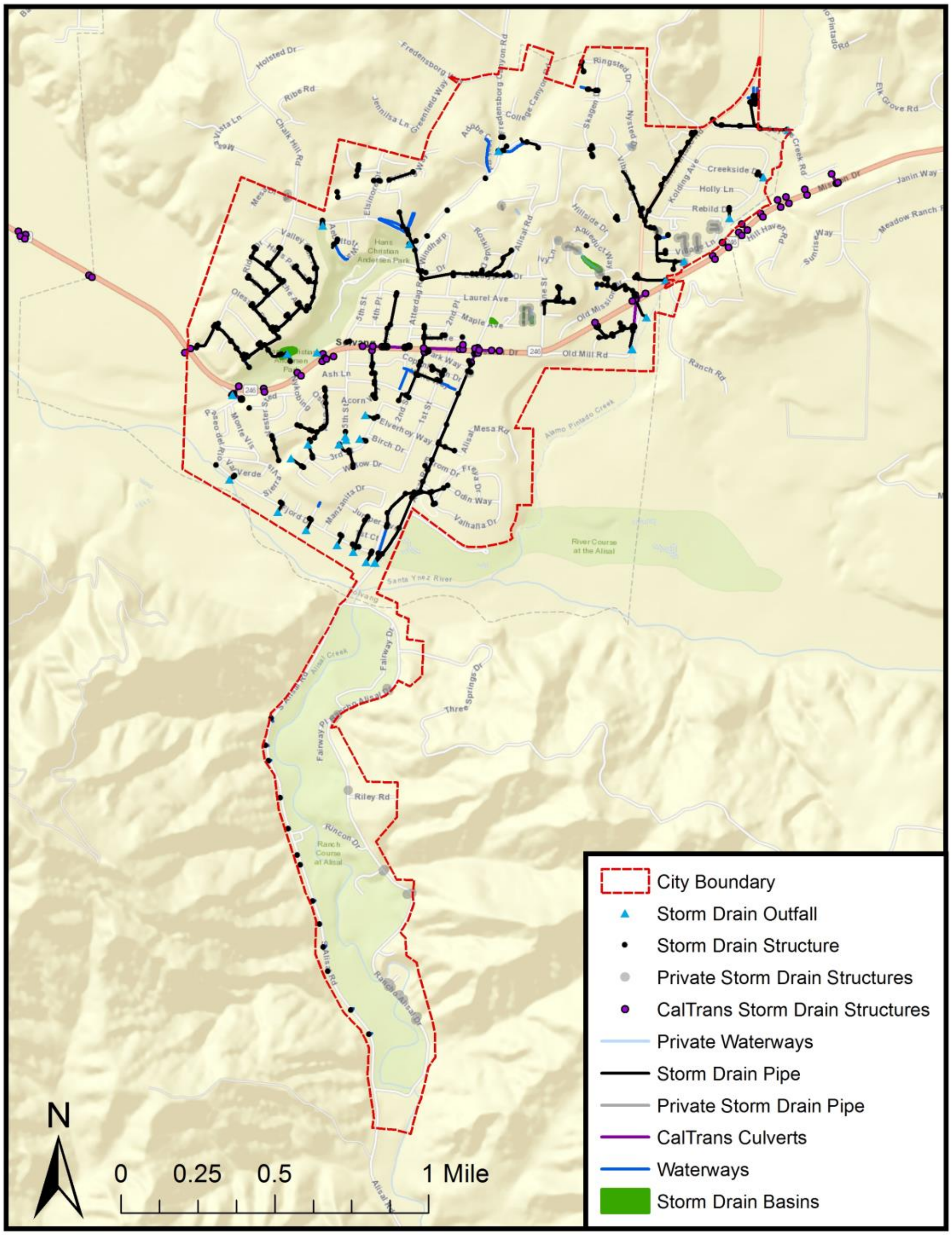

Figure 3-2. Location of City and non-city owned storm drain network structures

3.2.1 Storm Drain Lines

Approximately 475 storm lines (or conduits) were provided by the City for this analysis. The existing data were not sufficiently complete to form a full and uninterrupted storm drain network from end to end, which is necessary for modeling. Several additional conduits were inferred to hydraulically connect the provided isolated nodes to the larger storm drain network. In these instances, the location of pipes that likely exist were assumed based on shortest distance to the nearest node. They were also used to connect outlets and grates along roadways, over bare earth, or to connect outfalls to nearby waterways. The entity type for inferred conduits in the GIS database was classified as “model conduit” for both surface and subsurface connections. The result of supplementing the received dataset with assumed conduits was a complete and unbroken storm drain network summarized in Table 3-1.

Table 3-1. Summary of Quantity, Length and Ownership of Major Conduit Entity Types

Entity Type	Owner	Quantity	Length (feet)
Pipe	City	351	44,245
	Caltrans	50	5,724
	Private	27	2,205
	Total	***469***	***52,304***
Surface Conveyance	City	39	6,058
	Private	6	932
	Total	***45***	***6,990***

3.2.2 Storm Points

Storm points (or nodes) are storm drain infrastructure, such as inlets, manholes, headwalls and cleanouts, situated between conduits, which connect the conduits to the surface, other conduits, or outfalls. The City provided node locations which are quantified in Table 3-2. A ‘Storm Index’ attribute, which acts as a unique identifier, was also provided for nearly all City-owned nodes. This attribute will be maintained for asset identification in the deliverable geodatabase to provide continuity between the received and delivered database. In addition to these nodes, five water quality/retention basins were identified (Table 3-3); the City also provided the locations of 29 outfalls for the drainage network.

Table 3-2. Inventory of Storm Point Entities

Owner	Quantity	% of Total
City	395	75%
Caltrans	75	14%
Private	56	11%
Total	***526***	***100%***

Table 3-3. Water Quality and Detention/Retention Basin Quantities

Name	Owner	Detention/Retention
Skytt Mesa	Private[1]	Detention
Alisal Oaks	Private	Detention
Mission Oaks	Private	Detention
Solvang Senior Apartments	Private	Retention
Merkantile[2]	Private	Retention

1. Publicly maintained by City through the Landscape and Lighting Maintenance District
2. Merkantile is currently in planning/design phase and was not modeled

3.3 IMPERVIOUS COVER

To generate high-resolution land cover data, remotely-sensed imagery was used to classify surfaces between impervious and pervious. The infrared band (along with the red spectrum band) of high-resolution satellite imagery can be used to differentiate between surface covers as the infrared band is typically reflected by vegetation and absorbed by impervious areas (and vice versa for the red spectrum band). The measured signals for these bands from the imagery data were converted to the Normalized Difference Vegetation Index (NDVI), which was then analyzed to determine the local threshold value of the NDVI between impervious and vegetated surfaces. Threshold values were iteratively varied until surface cover classification best matched a visual inspection of satellite imagery for areas across the City bounds. Finally, areas of open water were classified separately using municipal data, as these are often misclassified as impervious using this automated methodology. Based on this analysis, the total impervious area within the City's drainage area was identified (Table 3-4) and the results can be viewed in the map in Figure 3-3. Land cover data from remotely-sensed imagery across the City.

Table 3-4. Total Impervious Area

Description	Area (sq. mi)
Total City Drainage Area	2.64
Impervious Area of City Drainage Area	0.77
% Impervious	**29%**

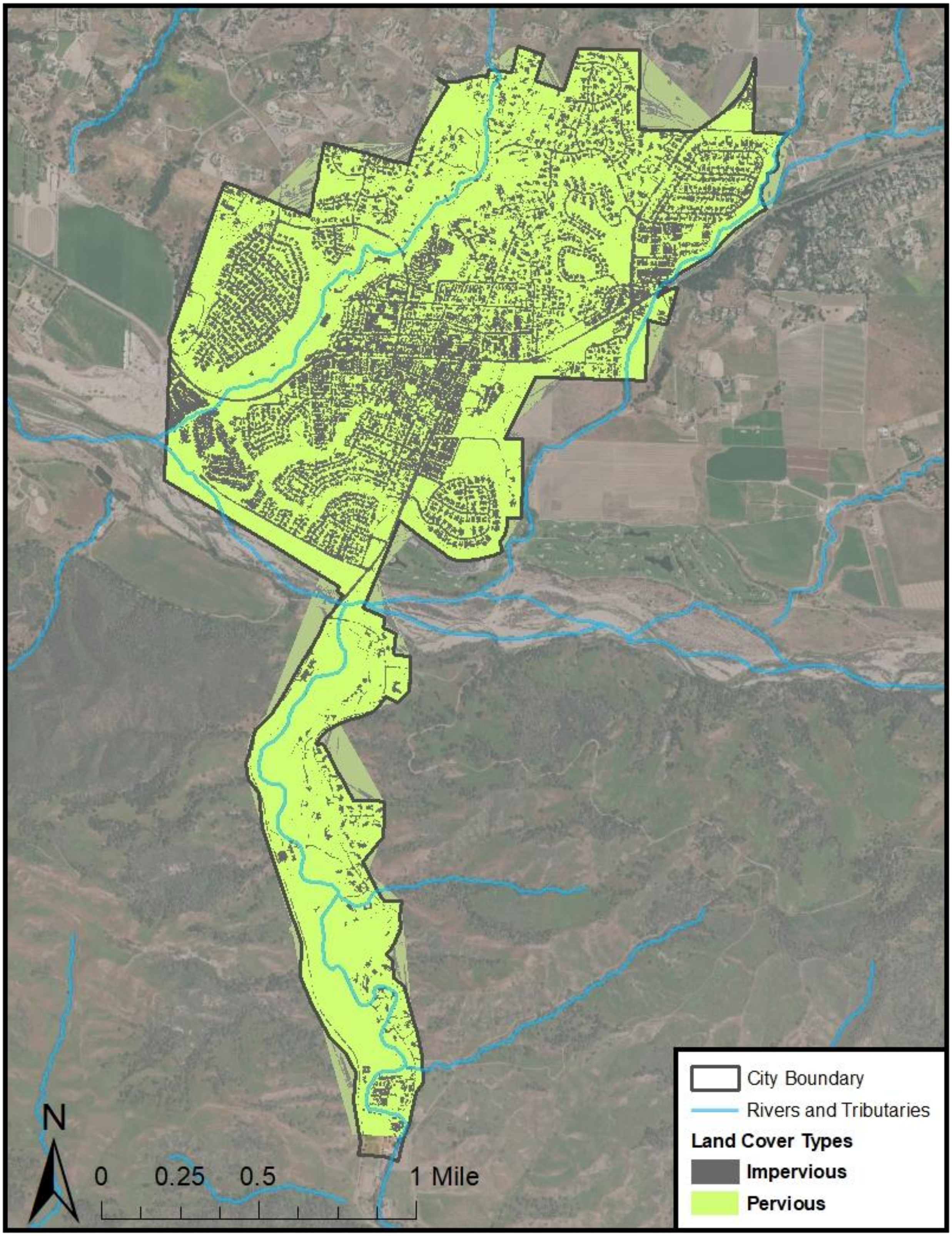

Figure 3-3. Land cover data from remotely-sensed imagery across the City

3.4 RECENTLY COMPLETED/PLANNED DRAINAGE PROJECTS

To address drainage issues, several stormwater control and drainage improvement plans have been either recently completed throughout the City or are in planning stages at the time of this report. Projects include the Oak St. Drainage Improvement Project, FY 2014-15 Pavement and Drainage Improvement Project, Solvang Senior Apartments, Merkantile Shopping Center Redevelopment, Second Street Drainage Improvements (Phase 1 and Phase 2), and the Cottages on Old Mission. Some of these projects are detailed here to highlight existing drainage improvement plans to be considered alongside those projects proposed based on modeling results. A table of all recently completed and planned projects are included in Appendix E for reference.

3.4.1.1 The Merkantile Shopping Center

The Merkantile is an existing shopping center located between Mission Drive (Highway 246) and Old Mission Drive. The project consists of new and redeveloped building construction, parking lots, driveways, and landscaping. The new site layout has been improved for stormwater management by grading impervious area to drain to pervious areas as a natural solution. Stormwater control measures include permeable paver areas functioning as infiltration basins and a bioretention area. Runoff generated from the site is directed to one of the several stormwater control measures.

3.4.1.2 Second Street Drainage Improvements (Phase 1)

This project site is a parking lot located northeast of Second Street between Park Way and Copenhagen Drive. The project consists of parking lot construction with drainage improvements to alleviate potential flooding issues of storms exceeding a 10-year storm flow. Drainage improvements include installation of a 36” storm drain, storm drain inlet, and storm drain manhole.

3.4.1.3 Cottages on Old Mission

The Cottages on Old Mission project is a development project proposed for a vacant lot at the west end of Old Mission Dr, near the intersection of Pine St and Mission Dr (Highway 246). The developers propose eight new homes, additional parking for the area, public street updates, and storm drain system improvements. Improvements will consist of a permeable paver parking lot, landscape drain collection system, as well as manhole and inlet installations. The drainage system and permeable pavers will encourage retention and infiltration of stormwater on site while preserving existing trees.

3.5 HISTORICAL FLOOD AREAS

The City provided locations throughout the city that have historically experienced flooding. These flooding issues were classified as either system-specific or related to collection of debris at locations along the drainage system. Debris accumulation was not included in the modeling effort, since predicting this type of system-effect would be subject to high spatial variability as well as landscaping activities and vegetation type, which are difficult to fully account for in a predictive manner. However, throughout the modeling timeframe, results were shared with City staff. Modeled flooding locations were found to align with known historic areas of flooding in the City, thus validating the predictive capabilities of the modeled storm drain network. Prominent regions of historic and potential flooding (see Figure 3-4 and Appendix D) are located in the northeast of the city near Mission Drive and Copenhagen Drive, as well as Alamo Pintado Road and Viborg Road, and along South Alisal Road.

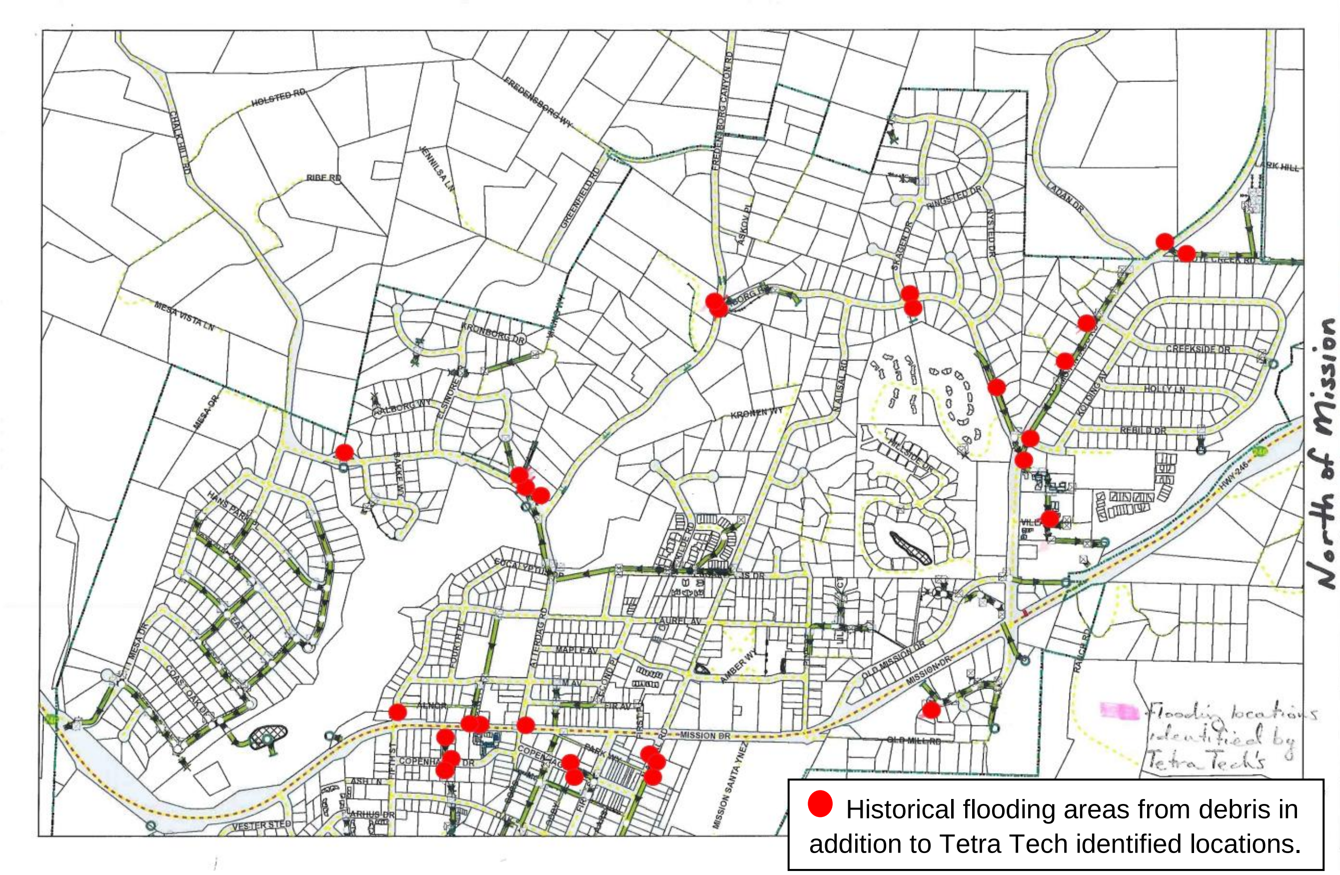

Figure 3-4. Historic flooding map

3.6 PRECIPITATION AND EVAPORATION

A regional hyetograph and storm depth for each frequency was obtained to simulate precipitation events in the model. NOAA Atlas 14-point precipitation frequency storm depth estimates were calculated from the rain gage at the Solvang Water District (Table 3-5). Additionally, the storm depths reported in the County of SBFCD Standard Conditions for Project Plan Approval were referenced for verification. The County values were lower than NOAA Atlas 14 and were more regional in nature, not site specific. Therefore, NOAA values were used for the modeled events. The Santa Barbara County 10-year frequency hyetograph was used to temporally distribute rainfall over a 24-hour period for storms less than or equal to a 25-year frequency. For the 50- and 100-year storms, the 100-year frequency County hyetograph was used. Model results are very sensitive to rainfall inputs as these are the main drivers of flooding. If rainfall estimates are revised in the future using additional data or with climate change in mind, it is advised that models are re-run and flooding locations updated as needed.

Table 3-5. Modeled Design Storm Depths

24 Hour Design Storm Frequency (return years)	2	5	10	25	50	100
County of Santa Barbara Standard Conditions Rainfall Depth	2.83	4.1	4.93	5.97	6.72	7.45
NOAA Atlas 14 Rainfall Depth Gage 80-0393	3.56	4.68	5.58	6.79	7.71	8.63

The County of Santa Barbara reported monthly evapotranspiration values as part of the California Irrigation Management Information Systems Reference Evapotranspiration Table. The values reported were gathered and are compiled in Table 3-6 below. Evapotranspiration rates were included in the model to account for water loss due to evaporation.

Table 3-6. Evapotranspiration rates for the City of Solvang

January	February	March	April	May	June
2.0	2.0	3.3	4.3	5.0	5.6
July	**August**	**September**	**October**	**November**	**December**
6.1	5.6	4.4	3.7	2.2	1.6

3.7 GROUNDWATER DEPTHS

Groundwater levels in the project area were found using United States Geological Survey (USGS) monitoring wells within a one-mile radius of the City. There were three wells, gage 006N031W16N002S, 006N031W10F001S, and 006N031W11D004S, with groundwater depth information in the last 30 years. The minimum depths to groundwater found in the record are summarized in Table 3-7 below and the locations of these wells are shown in Figure 3-5. The minimum observed groundwater levels at the three wells indicate that infiltrating BMPs will not be impacted by groundwater interactions and thus do not require any further subsurface parameterization.

Table 3-7. Depth to Groundwater Level at nearby gages

	006N031W16N002S	006N031W10F001S	006N031W11D004S
Minimum depth to groundwater (ft)	23.4	62.59	25.67

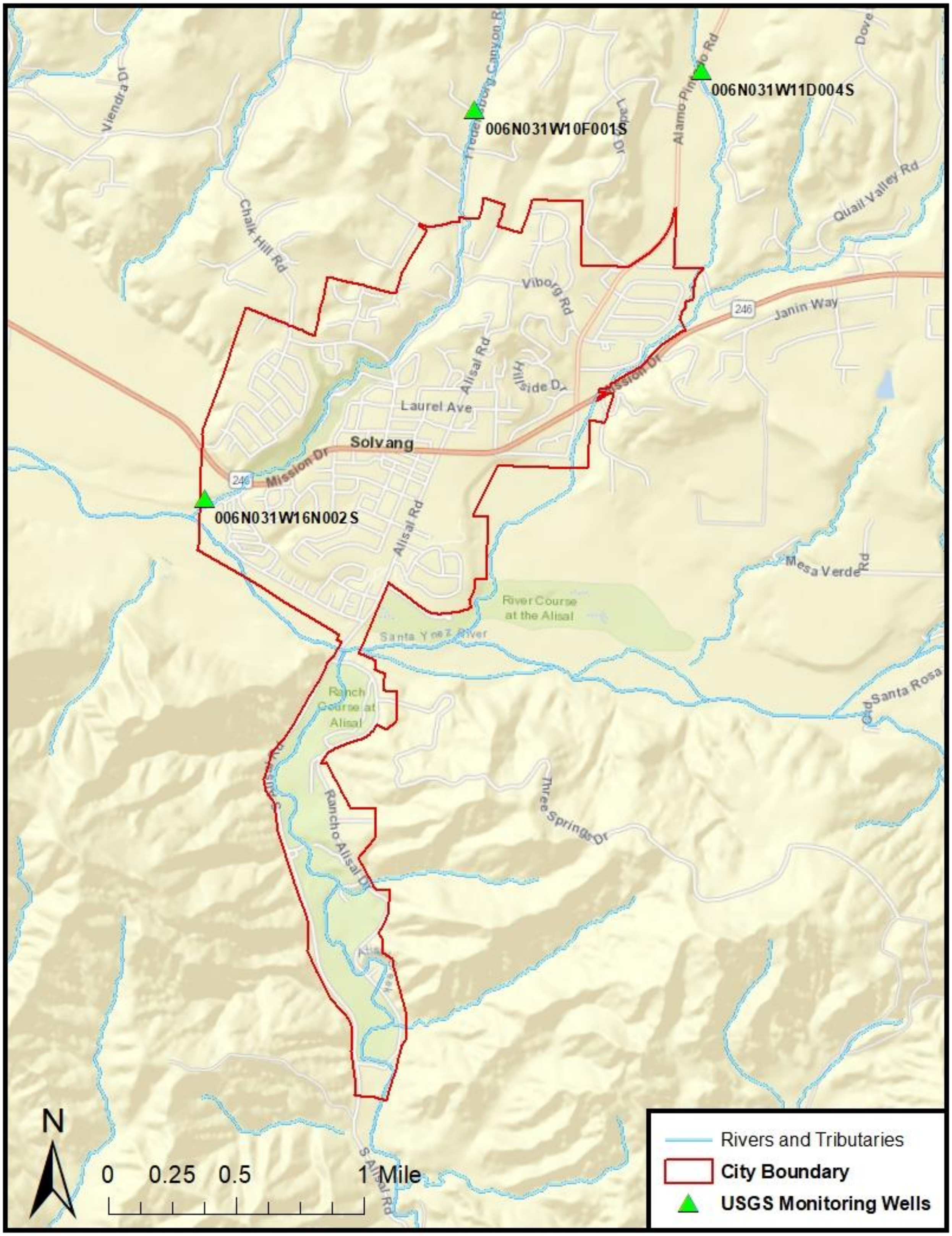

Figure 3-5. USGS monitoring wells within a 1-mile radius of the City

3.8 100-YEAR FLOODPLAIN

The Solvang Reach of the Santa Ynez River is located south of the residential and commercial areas of Solvang, north of Fjord Drive. Figure 3-6 shows the spatial extent of the floodplain associated with the Santa Ynez River. The City also has an additional two waterbodies to the east and south that have the potential to flood. Along the east City border is the Alamo Pintado Creek which runs north to south until it connects to the Santa Ynez River (Figure 3-7). Approximately 0.09 square miles of the 100-year flood plain surrounding this creek at the southern portion of the city boundary is within the City's jurisdiction. Finally, the Alisal Creek is located at the southernmost end of Solvang flowing north parallel to Alisal Road. Alisal Creek is also a tributary to the Solvang Reach of the Santa Ynez River. Flood zones are needed to ensure and verify that they are properly represented in modeling results. Note that the different colors of the floodplain maps correspond to Federal Emergency Management Agency (FEMA) special flood hazard areas (SFHA) with different expected flooding depths and risk, but they are all delineated flood zones.

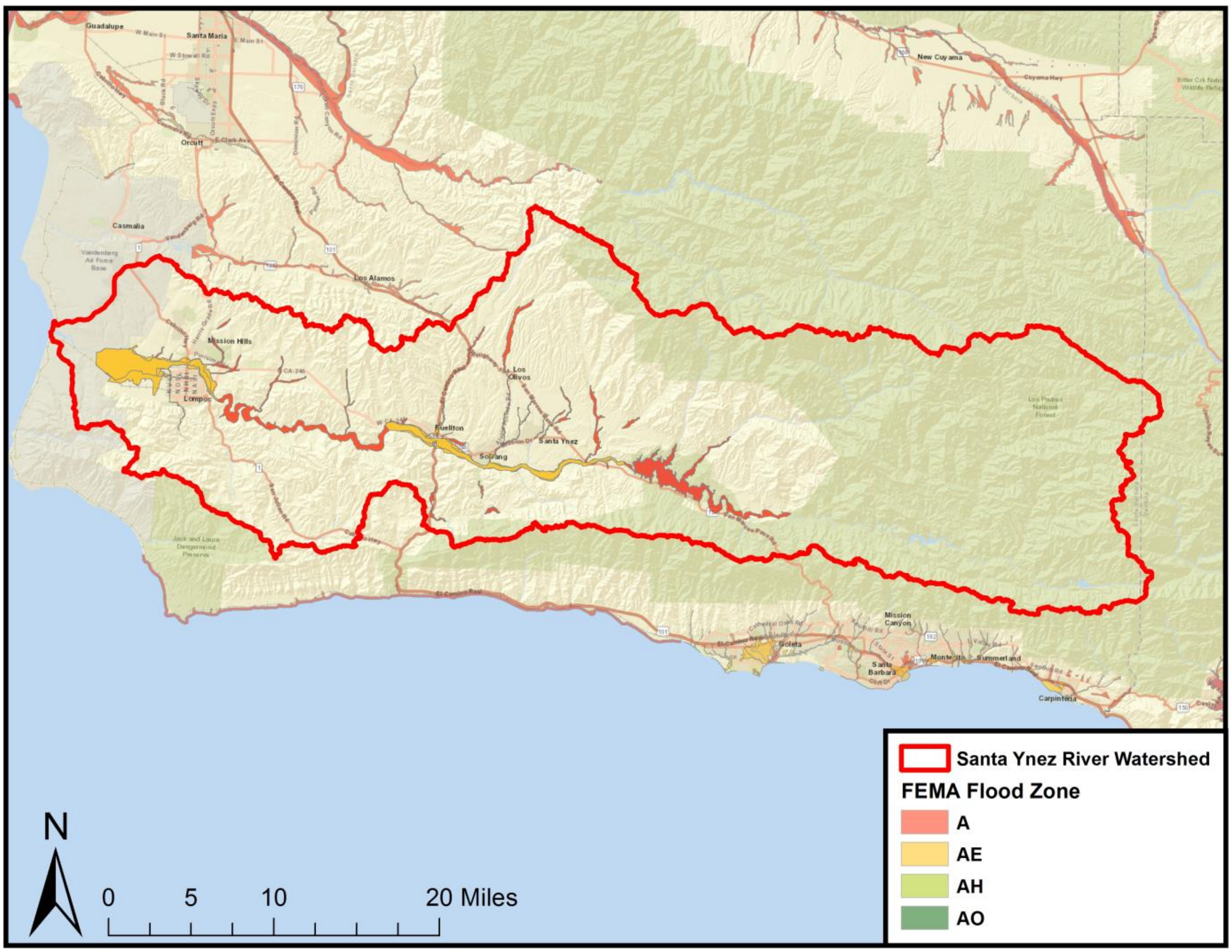

Figure 3-6. FEMA special flood hazard areas in the Santa Ynez River Watershed

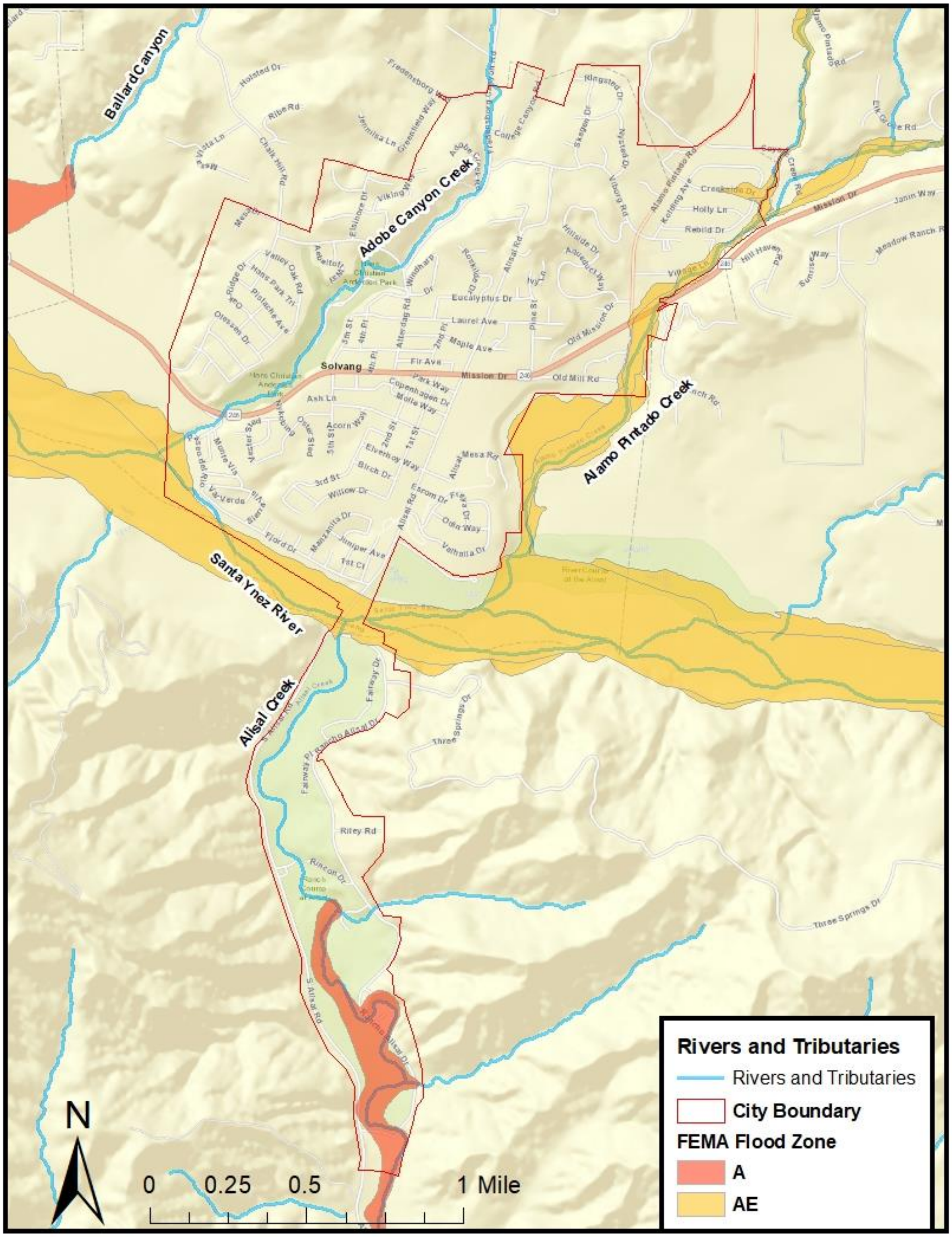

Figure 3-7. FEMA special flood hazard areas in the City

3.9 SOILS

Surficial soil types and their distribution across the City inform the infiltrative capacity of soils and runoff production potential. These soil characteristics are some of the determining factors of whether surface runoff remains on-site or flows to the drain network. Soils data were obtained from the Web Soil Survey portal provided by the US Department of Agriculture (USDA) National Resources Conservation Service (NRCS 2017). This dataset provides a soil name (e.g., Bolsa silt loam, Alo clay, etc.) and geographic extent across the City (Figure 3-8). Each soil name is classified as one of four hydrologic soil groups (HSG), which have associated modeled soil characteristics. The HSGs are put into the modeling platform (Green-Ampt soil infiltration method) from the Structural BMP Prioritization Tool (SBPAT) Manual (Geosyntec 2012). These parameters are summarized below in Table 3-8.

Table 3-8. Hydrologic Soil Group Parameters

Hydrologic Soil Group	A	B	C	D
Hydraulic Conductivity (in/hr)	3.75	0.225	0.1	0.025
Wetting Front (in)	2.9	5.04	8.6	10.47
Initial Moisture Deficit (in/in)	0.32	0.36	0.24	0.29

3.10 TOPOGRAPHY

Elevation products are critical inputs to simulate stormwater routing across a drainage region. Developing an understanding of hydrologic routing across a landscape requires a high-resolution Digital Elevation Model (DEM). The best available datasets are provided as Light Detection and Ranging (LiDAR) point clouds, which are then processed in GIS into DEMs. The primary LiDAR dataset used in this effort was provided by the City with a typical point spacing (horizontal resolution) of approximately 1 foot and vertical resolution of up to 1 foot. For elevation data outside of the city limits, the National Elevation Dataset with a coarse 10-meter resolution was applied. Elevation data was used to derive overland flow paths and drainage area delineation in the model.

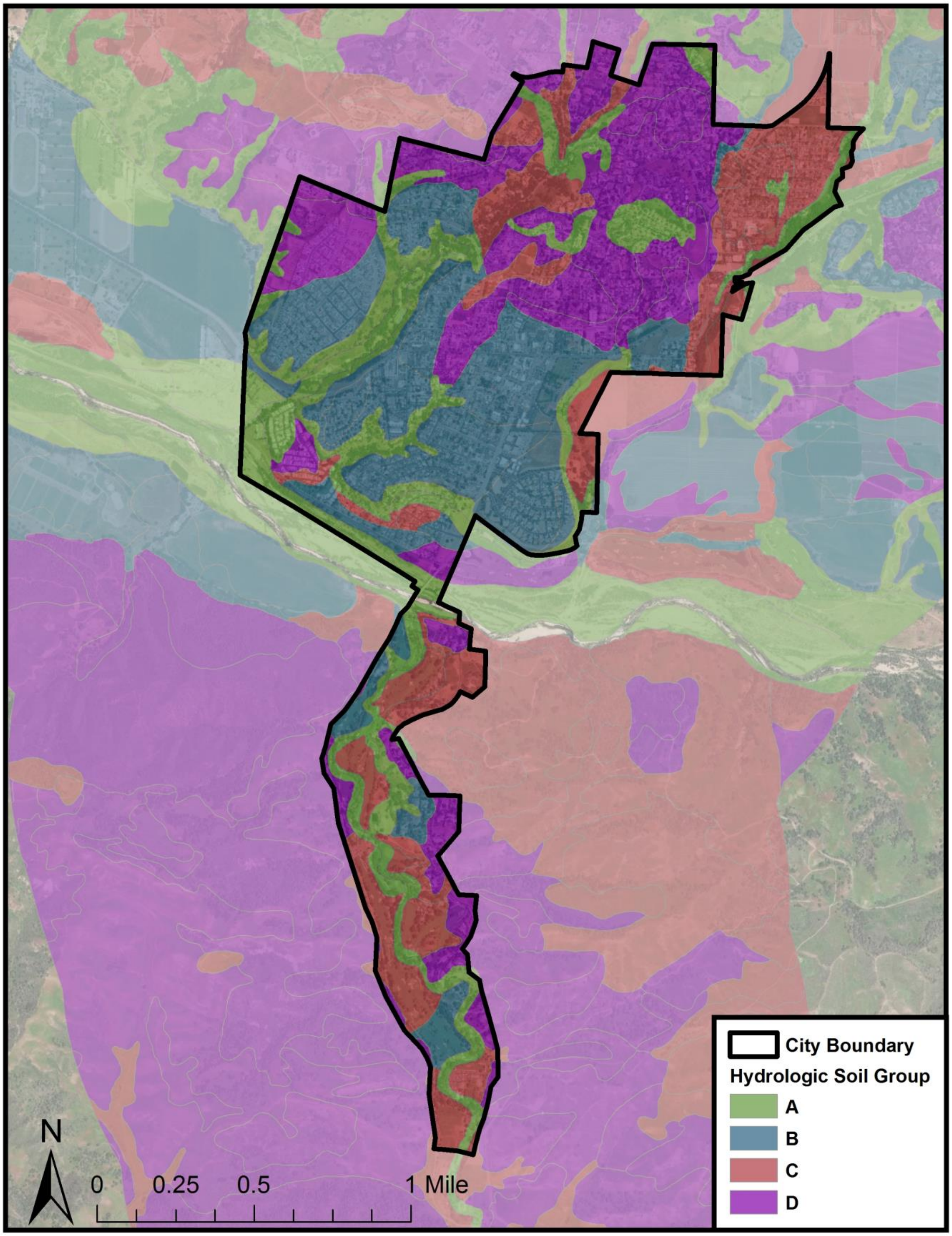

Figure 3-8. Hydrologic Soil Groups and their distribution across the City

4.0 MODEL METHODOLOGY

To assess the City's drainage system, a full H&H analysis was performed. The focus of the hydrologic assessment was the quantification of runoff and peak flow rates from selected design storms. Multiple design storms were simulated to capture the varying levels of protection offered by the existing drainage system. The hydraulic assessment analyzed the capacity of the existing stormwater conveyance system (streets, pipes, and box structures) to drain and convey the runoff determined from the hydrologic analyses. The H&H analysis was performed using a single integrated model: the Personal Computer Storm Water Management Model (PCSWMM) platform. Results from the PCSWMM model indicate where deficiencies in the stormwater conveyance may exist and their degree of magnitude.

4.1 HYDROLOGIC MODEL DEVELOPMENT

The two primary inputs to the hydrologic model are precipitation (hyetograph and rainfall depth) and land surface composition. Land surface composition uses various geospatial datasets (e.g., soil type, imperviousness, etc.) to characterize the upstream drainage area to each inlet in the network. This level of modeling detail at the inlet scale enables a robust hydrologic simulation of approximately 368 discrete network inlet drainage areas and provides a resolution that is appropriate for meeting the requisite performance criteria.

4.1.1 Precipitation

To simulate rainfall in the model, an appropriate hyetograph and storm depth for each storm was developed. NOAA Atlas 14-point precipitation frequency estimates were used to estimate the storm depths for the modeled events (Table 4-1). The Los Angeles County hyetograph was used to temporally distribute rainfall over a 24-hr period (Figure 4-1).

Table 4-1. Modeled design storm depths

24-hour Storm Event	Precipitation Depth (in)
10-year	3.56
100-year	8.63

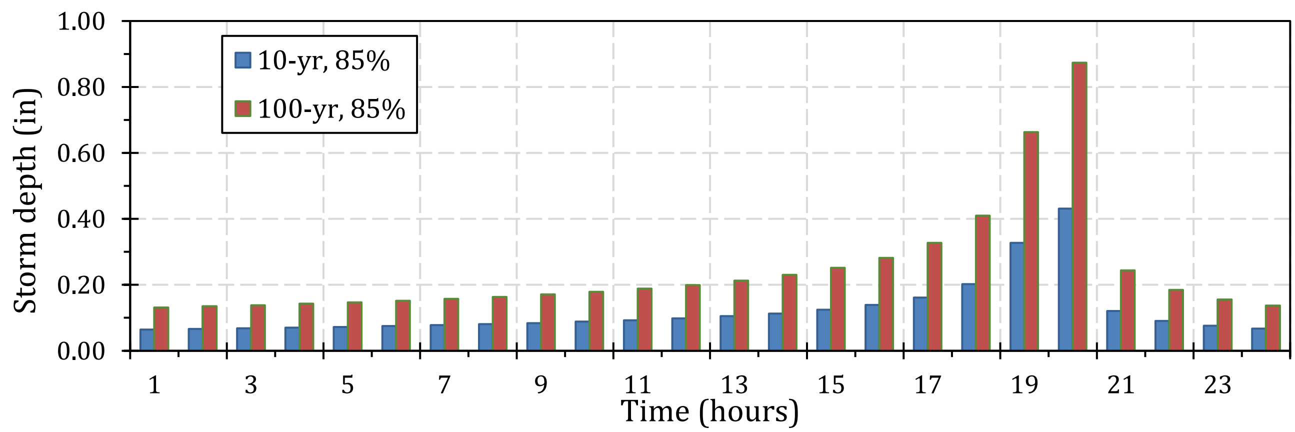

Figure 4-1. Hyetograph for the 10- and 100-year, 24-hour storm events

4.1.2 Subcatchments

The drainage areas within the City were delineated upstream of every node with an inlet entity type (e.g., catch basin, grate, etc.) using ArcGIS tools, and high-resolution LiDAR data. Subdividing the City into discrete subcatchment areas enables characterization of spatial variability and captures the unique composition of each drainage area. Model parameters (e.g., inlet type, pervious and impervious area, flow length, slope, impervious cover, Manning's n, depression storage, zero impervious, infiltration method and values) were developed to appropriately capture these nuances.

Inlet type

Most (~99%) features within the City-provided data included an entity type. If the entity type was an inlet (e.g., catch basin, inlet, or grate) it was assumed to transmit stormwater from the land surface to the storm drain network, and an upstream drainage area to the entity was delineated (Figure 4-2). The area for each subcatchment was calculated using ArcGIS tools.

Flow length

An important parameter for estimating timing of peak flows within PCSWMM is the subcatchment flow length. Flow length refers to the length of the overland flow path from the furthest drainage point of the subcatchment to its discharge point. Flow length, in conjunction with the subcatchment area, enables subcatchment width to be calculated—all three of these values inform the quantity and timing of surface runoff for each subcatchment. Arc Hydro (a set of advanced tools developed for use within ArcGIS) was used to calculate flow length for each individual subcatchment using the DEM (Maidment 2002).

Slope

As with flow length, slope for each catchment was calculated using the DEM. The slope across each subcatchment was averaged and applied as a single value.

Impervious Cover

To characterize the impervious cover of each subcatchment, the infrared band of the high-resolution satellite imagery was used. The measured signal from these bands was used to differentiate land cover based on the reflection from vegetation and the absorption of impervious cover. These values were converted to NDVI to use the local threshold value between vegetation and imperviousness. Percent imperviousness across each subcatchment was averaged and applied as a single value to each subcatchment.

Manning's n

Manning's n is the roughness value associated with overland flow that considers the impact of precipitation, drag over a surface, and obstructions in the flow path. Manning's n must be provided for overland flow on both impervious and pervious surfaces; in both cases composite "look-up" values for Manning's n were used to approximate the modeled value for each (Engman 1986). For all subcatchments, the roughness coefficient for impervious areas was assumed to be 0.011, which corresponds to smooth surfaces such as concrete or asphalt. Aerial imagery of City pervious areas indicated surface cover was mostly low grass, therefore the corresponding Manning's n of 0.015 was used universally for pervious areas.

Depression Storage

Consistent with Manning's n, look-up values were applied for the pervious and impervious depression storage parameters: impervious surfaces were set at 0.10 inches, and pervious surfaces were set at 0.20 inches (ASCE 1992).

Zero Impervious

Zero impervious is defined as the percent of impervious area without depression storage. The default value within PCSWMM of 25% was assumed for all subcatchments.

Infiltration Method

The Green-Ampt method of infiltration was used to simulate stormwater saturation and infiltration into the subsurface in modeled pervious area. The USDA NRCS dataset (NRCS 2017) was used to extract soil data across the City, and standard look-up values were used to correlate soil classes (e.g., sandy loam) to Green-Ampt soil parameters (**Error! Reference source not found.**). For each delineated drainage area, a weighted average of the contributing soil area's parameter values within each area were tabulated. The distribution of HSGs is shown in Figure 3-8.

Table 4-2. Green-Ampt parameters for different soil classes (Rawls et al. 1983)

Soil Class	Porosity	Wetting Front Suction Head (in)	Saturated Hydraulic Conductivity (in/hr)
Sand	0.437	1.95	4.74
Loamy sand	0.437	2.41	1.18
Sandy loam	0.453	4.33	0.43
Loam	0.463	3.5	0.13
Silt loam	0.501	6.57	0.26
Sandy clay loam	0.398	8.6	0.06
Clay loam	0.464	8.22	0.04
Silty clay loam	0.471	10.75	0.04
Sandy clay	0.43	9.41	0.02
Silty clay	0.479	11.5	0.02
Clay	0.475	12.45	0.01

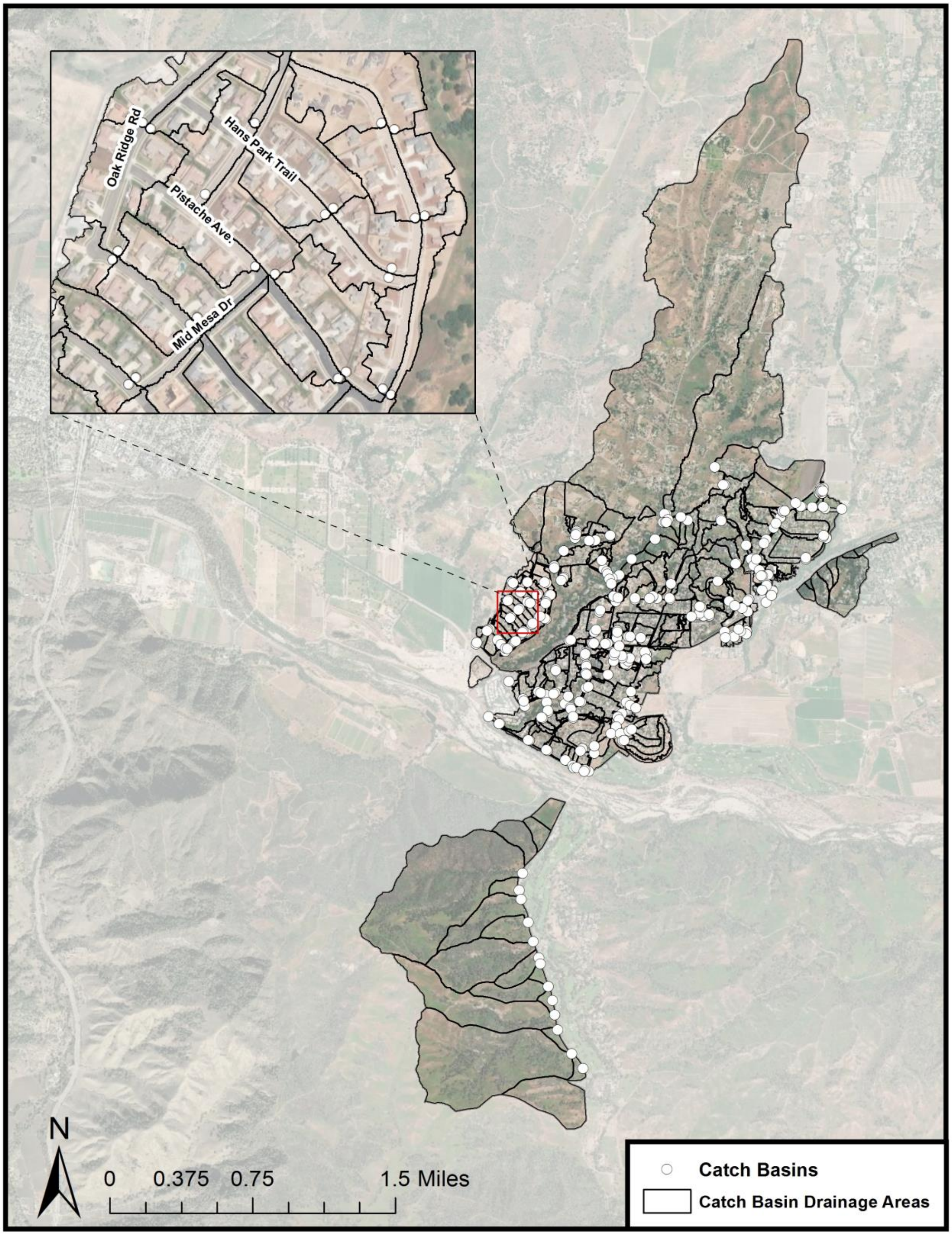

Figure 4-2. Location of all delineated drainage areas draining to their respective inlet node

4.2 HYDRAULIC MODEL DEVELOPMENT

To generate a comprehensive hydraulic system, the existing storm drain network provided by the City was amended and adapted to be imported into PCSWMM. The major components of this network are comprised of a system of conduits and nodes, which convey surface runoff downstream to detention storage, or outfalls. In addition to the City-provided conduits and nodes, a street flow system was developed to assess street flooding criteria. The street flow system enables stormwater to overflow from the subsurface network of conduits to simulate overflow routing between inlets along the roadway. Finally, boundary conditions of the model were established based on the City's drainage system.

4.2.1 Storm Drain Network

The storm drain network modeled in PCSWMM was predominantly comprised of the City-provided inventory data; however, the modeling process required a fully articulated storm drain system with key attributes (e.g., invert, size, slope) to be specified. Assumptions were made to inform the system and are described in further detail in the following sections.

4.2.1.1 Nodes

Nodes serve as the connection points between conveyance structures, as well as inlets to convey surface runoff into the storm drain network in PCSWMM. Modeling assumptions associated with various node attributes are explained in the subsections below.

Invert Elevation

Invert elevations were not included for all the junctions provided in the GIS data. Of the 540 junctions, the invert elevations for 266, or 49%, were known. The remaining 274, or 51%, required characterization using a set of assumptions, which either: (1) interpolated the invert elevation between two known nodes when possible or, (2) assumed the invert elevation was 2 feet below the ground surface plus the diameter of the pipe.

Rim Elevation

Rim elevations for nodes were obtained using the DEM, where elevations at the location of the nodes was applied.

Ponded Area

Ponded area in PCSWMM is the footprint around a node where stormwater collects when the conduit system is above capacity (i.e., when runoff at a node exceeds the intake capacity, stormwater will pond). Ponded areas create an opportunity for excess stormwater to flood and store until capacity in the conduit is restored. Each node in the system was given a ponded area of 1,000 square feet to allow for water surcharging from the system to pond. The maximum height and volume of flooded stormwater from each node in the model is used to assess localized flooding at each location.

Surcharge Depth

Nodes were assigned a surcharge depth based on the type of the surface feature. A surcharge depth is a value that can be assigned individually to each node and indicates the depth of stormwater that can accumulate on the surface before flooding occurs. When surcharge height is zero at a node, stormwater floods at the rim elevation; however, if the surcharge height is changed to three feet for example, stormwater will only flood at the node if stormwater surcharges three feet above the rim elevation. By default, all nodes have a surcharge depth of zero feet, but increasing the surcharge depth to a greater value enables upward pressure associated with specific entity types to be simulated. Table 4-3 shows how node types are grouped by surface feature and assigned a surcharge depth.

Table 4-3. Surcharge depth and reasoning for node types grouped by surface feature

Node grouping (Node types included)	Surcharge depth (feet)	Reasoning
Open surface (surface overflow, street flow, etc.)	0	There is no overhead surface feature that would prevent water from flooding the node immediately.
Partially open surface (Grate, catch basin, etc.)	2	There is an overhead surface feature which restricts surcharging stormwater but is relatively minimal, therefore flooding at the node is possible when sufficient pressure exists.
Closed surface (Manhole, cleanout, etc.)	5	A significant overhead structure exists (closed surface) therefore flooding at the node would require significant pressure before stormwater could flood at the node.
No surface (Transitions, plugs, etc.)	∞	These nodes do not have a surface feature and are therefore incapable of flooding at the surface. The assigned surcharge value is so great it inhibits the possibility of flooding.

Road Type

One of the main criteria for assessing existing infrastructure capacity is the height of water surface elevation (WSE) along roadways for the 100-year storm. A designated road type (and corresponding curb height) is assigned for each node within the right-of-way (ROW) enabling this flood criteria to be assessed.

Determination of road types used the ‘Centerlines_SBC’ geospatial layer provided by the City. Transects were created based on their ‘Subclass’ type. This process enabled simulation of stormwater as it flows between inlets by assigning roadway dimensions to each node and conduit within the street flow system.

Inlet flow

As the intermediary between surface and subsurface flow, inlets play a significant role in how and where flooding may occur, specifically their type (grate, curb opening, or combination; Figure 4-3), length and sump condition (in sump or on grade).

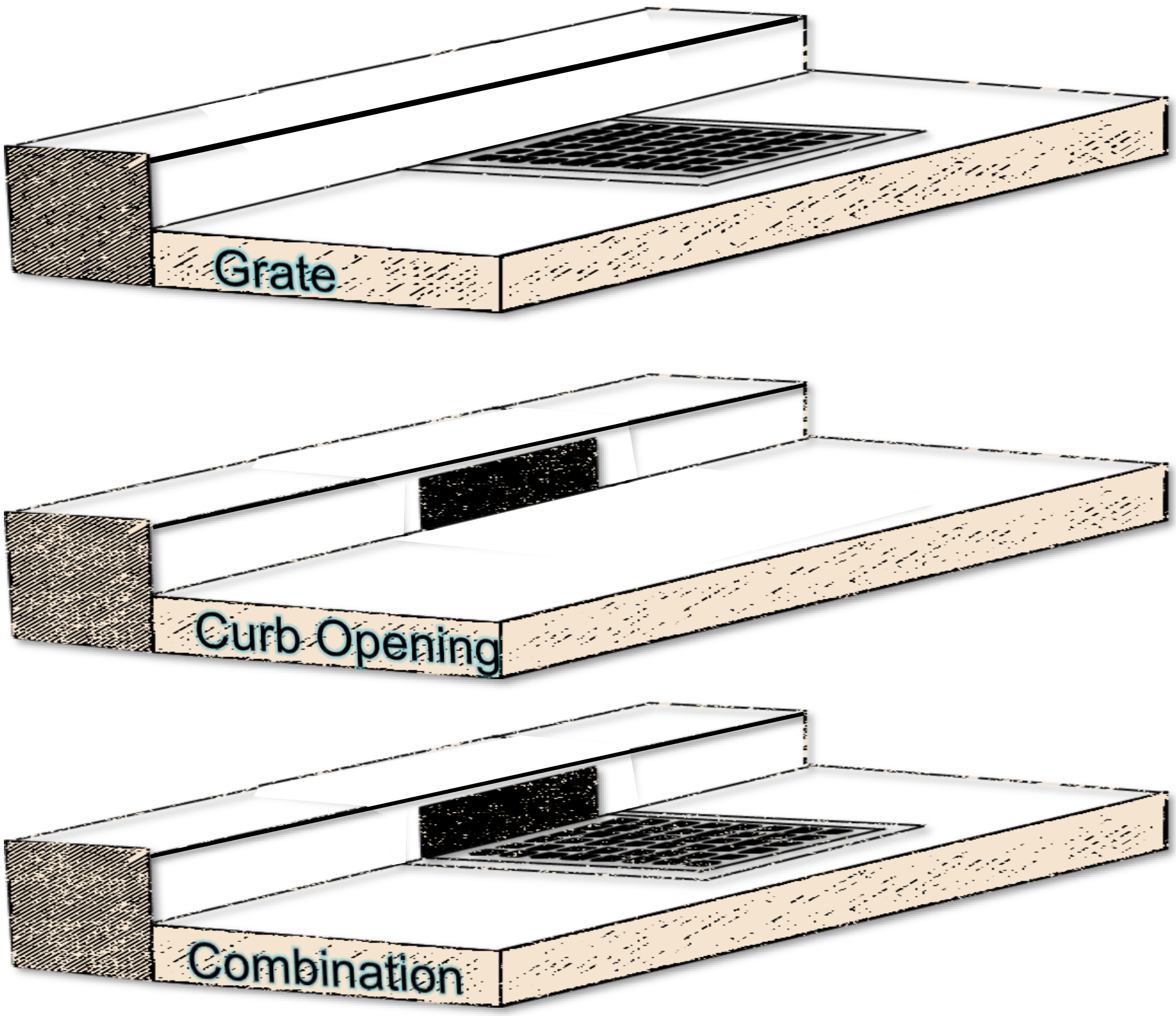

Figure 4-3. Three major inlet variations considered

Nearly all City inlet nodes had a size (curb opening or grate dimension) provided. All three inlet configurations were modeled for both in sump and on grade scenarios for 2-foot increments of length from 2' to 20' using the Federal Highway Administration (FHWA) Hydraulic Toolbox. When dimensions for an inlet or catch basin were not provided, the sizes of local inlets were found and applied to basins. When provided lengths fell in between the standard lengths, the closest size rounding down was used as a conservative estimate.

4.2.1.2 Conduits

Conduits are the stormwater conveyance structures in the model, which include subsurface pipes, culverts, channels, and surface drains. The process for determining model attributes are indicated in the sections below.

Geometry (Size)

Of the 380 pipe conduits, including public, private, and abandoned, within the complete storm drain network, size in inches (e.g., diameter) was provided for approximately 96%. If a conduit of known size was adjacent to a conduit of unknown size (whether upstream or downstream), the lesser size was applied to the adjacent unknown.

The GIS database indicates which conduit sizes were provided in the original dataset ("known") and which were assumed from the above methodology ("assumed"). If a conduit's size is assumed in the existing condition and upsized in the proposed condition, it is recommended that the first step is to provide field verification to ensure that the size of the proposed infrastructure is not already in place.

Cross-section

Generally, conduit cross-sections were assumed from the feature type (e.g., earth or reinforced concrete box). However, the material type of 46 conduits were "unknown" (8% of the system by length). To determine which cross-section was to be assigned for each conduit, a series of assumptions were made in the following order:

1) When conduit size was a single value (e.g., 36 inches), it was assumed to be a circular cross-section
2) When a conduit did not have an associated material type or diameter, upstream and downstream conduits were assessed, and their material and size were applied

Manning's n

Several material types were indicated in the City-provided conduit data. For each material type, a roughness coefficient was assigned based on literature values (Table 4-4). Of the known conduits, 365 (76.8%) were reinforced concrete with a Manning's n value of 0.013. Other materials included corrugated metal pipe (CMP 6.1%), polyvinyl chloride pipe (PVC 4%), corrugated high performance polyethylene pipe (HP 1.7%), and cast in place concrete pipe (CIPCP 0.4%), as well as other materials of lesser frequency. Material types were not indicated for approximately 10% of the pipes in the City-provided conduit data. Therefore, a Manning's n of 0.013 was assumed for all unknown conduits, which is consistent with the reinforced concrete pipe (RCP) materials likely used.

Table 4-4. Manning's n for conduit material types (Ven Te, 1959; FHWA 1961; FHWA, 2013; ODOT, 2014)

Conduit Material	Symbol	Manning's n
Cast-in-Place Concrete	CIPCP	0.024
Corrugated Metal	CMP	0.024
Reinforced Concrete	RCP	0.013
High Density Polyethylene	HDPE	0.024
Polyvinyl Chloride	PVC	0.010

Ownership
All infrastructure within the City, regardless of ownership, was modeled; however, only City-owned infrastructure is recommended for upsizing. Approximately 10.6 miles (95% of total system length) of conduit length is publicly owned; the remaining 5% is private. Determining ownership for conduits was necessary to determine which of the conduits were eligible for upsizing.

4.2.1.3 Street Flow

The development of a street flow conveyance system, which enables flooded stormwater to route over land between inlets along the road, requires the road type for each simulated curb and gutter to be determined. To account for Road types were determined using the provided GIS 'Centerlines_SBC' layer. The City provided LiDAR was used to generate typical transects based on an analysis of several roads with the same subclass. The LiDAR, in combination with aerial imagery, was used to determine the typical roadway and parkway widths for each of the five road subclass types. The right-of-way (ROW) was determined from the combined capacity of the road and parkway. ROWs were used to model street gutter conveyance and identify flooding locations. The crowning and parkway slopes were all assumed to be 2% based on local design manuals and experience. From these values, cross-sections were developed for each road type classification see Figure 4-4 for an example). The roadway types and assumed widths based on geospatial analyses are summarized in Table 4-5. This process enabled simulation of stormwater as it flows between inlets by assigning roadway dimensions to the surface conveyance system.

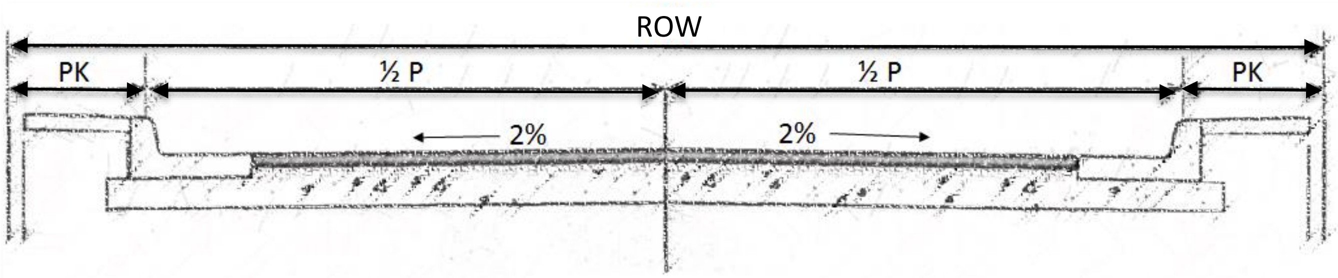

Figure 4-4. Standard roadway cross-section detail provided in the 2005 MPD

PCSWMM creates the street flow system parallel to anywhere the subsurface storm drain network exists. When subsurface storm drain conduits were located along the ROW, a conduit of matching length was modeled on the surface with the cross-section of the appropriate roadway type (as determined by the process described above) to represent gutter flow as well as the conveyance capacity in the ROW (to assess the 100-yr flood criteria). In total, over 8 miles of street flow conduits were simulated in this process. Figure 4-4 provides an example of the street flow conveyance and its matching subsurface conveyance in a profile view. Note in this illustration overflow can exist between catch basins even if they are not surcharging if inlet capacity is exceeded. Figure 4-5 provides an example of how the street flow system is modeled across the City from a plan view.

Table 4-5. Modeled road types and their associated dimensions

Description	Alley	Highway	Minor	Primary	Secondary
ROW (ft)	20	66	52	62	52
Curb Height (ft)	0.5	0.5	0.5	0.5	0.5
Half Street Width (1/2 P) (ft)	10	25	20	25	20
Parkway (PK) Width (ft)	0	8	6	6	6
Interior Street Grade (%)	2	2	2	2	2
Exterior Street Grade (%)	N/A	2	2	2	2

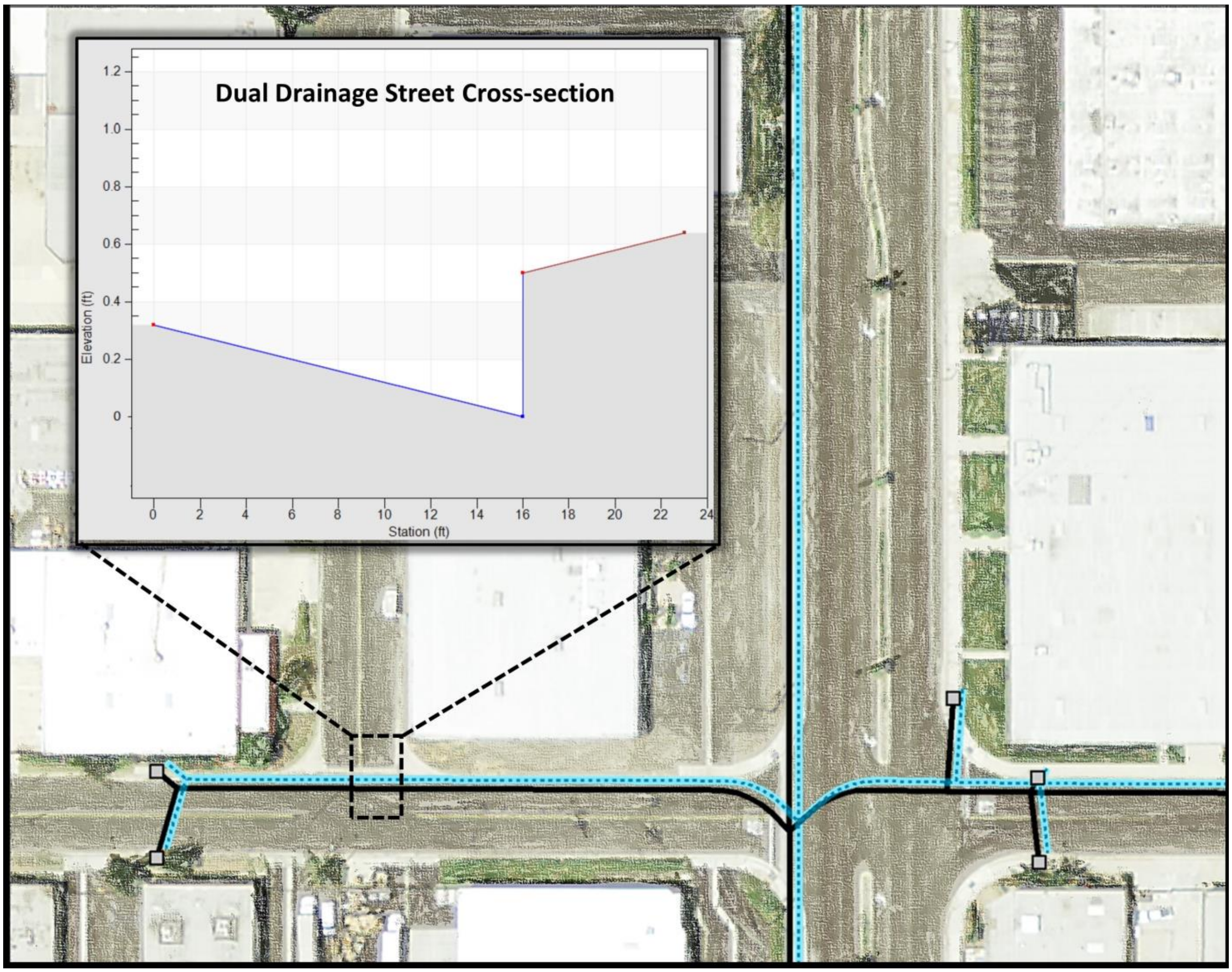

Figure 4-5. Illustration of street flow following the path of the subsurface conduits

4.2.1.4 Storage Elements

There are four storm drain basins currently being implemented in the City. These were modeled in PCSWMM using the average height and footprints for the facilities. City-provided inventory data contained storage volume and basin footprints (Table 4-6)..

Table 4-6. Modeled existing detention facilities with associated storage capacity and footprint

Name	Type	Basin	Volume (cf)	Footprint (sf)
Skytt Mesa Detention Basin	Detention Basin	Adobe Creek Drainage Area	190,000	36,851.6
Alisal Oaks Apts Retardation Basin	Detention Basin	Alisal Road Drainage Area	12,500	4,780.32
Mission Oaks Retardation Basin	Detention Basin	Alamo Pintado Creek Drainage Area	60,984	21,873.8
Solvang Senior Apts Bioretention	Retention Basin	Alisal Road Drainage Area	2,832	2,078.02

4.2.1.5 Hydraulic Boundary Conditions

The purpose of this SSMP is to assess the capacity of existing infrastructure and propose improvements where deficiencies were found. Boundary conditions were therefore needed to represent outfalls to creeks and other tributaries. Boundaries were modeled as outfalls, which are terminal nodes of the drainage system. At these points, the receiving tributaries were assumed to have sufficient capacity for incoming flows.

5.0 EXISTING CONDITIONS MODELING DETAIL

The existing condition model incorporated the City-provided storm drain network to assess street flooding. Model results were compiled for the 24-hour, 100-year storm event. The volume of runoff and peak flows generated during the storm in PCSWMM quantify the level of service that the City's existing infrastructure can provide. Additionally, the existing model assessment highlights potential deficiencies throughout the City.

City storm drain structures located within the ROW were assigned a road type based on the roadways layer provided by the City. For the 24-hour, 100-year storm event, the WSE must remain within ROW or private street easement. This depth was assumed to be the outer parkway height. This was calculated assuming that the curb height was 6" and that the parkway was 6' wide with a 2% slope. As a result, the maximum depth of water in the ROW was 0.62'. Model results suggest that approximately 10% (49 nodes) of the existing nodes do not meet the maximum street flow depth criteria for the 100-yr event (Table 5-1). The model also assessed major causes of street flooding, which were categorized into pipe capacity, inlet capacity, storage capacity, and large drainage areas (Table 5-2).

The location and magnitude of street flooding within the City can indicate regions where broader systemic inadequacies or undersized stormwater infrastructure exists. The location, flooded volume, and cause of flooding are summarized for these areas in Table 5-3. See Appendix A for detailed exhibits illustrating these locations, the undersized infrastructure, and magnitude of modeled street flooding for the 100-year, 24-hour storm in conjunction with reported/observed flooding data received from the City.

Table 5-1. Flooded storm drain structures categorized by ownership of a 24-hour, 100-year storm event

Owner	# of Flooded Structures	% of Flooded Structures
Public	32	65%
Private	10	20%
Caltrans	7	14%

Table 5-2. Flooded storm drain structures categorized by flooding source of a 24-hour, 100-year storm event

Source of Flooding	# of Flooded Structures	% of Flooded Structures
Inlet Capacity	10	20%
Pipe Capacity	20	41%
Storage Capacity	8	16%
Large Drainage Area	11	22%

Table 5-3. Locations with flooding, volume, and cause

Location	Flooded Volume (ft^3)	Cause
Alisal Rd & Juniper Ave	5,882	Pipe Capacity
Chalk Hill & Fredensborg Cyn Rd	1,203	Pipe/Inlet Capacity
Copenhagen Dr & 2nd St	61,092	Pipe/Inlet Capacity
Coyote Creek Rd	11,898	Large Drainage Area
Elverhoy Way & 3rd St	Minor Street Flooding	Inlet Capacity
Maple Ave & Pine St	105,741	Pipe Capacity
Mission Dr & 4th Pl	20,720	Pipe Capacity
South Alisal Rd	11,630	Large Drainage Area
Viborg Rd	3,075	Inlet Capacity (Large Drainage Area), Pipe Capacity
Viborg Rd & Alamo Pintado Rd	7,486	Inlet Capacity (Large Drainage Area)
West Chalk Hill Rd	401	Inlet Capacity
Fredensborg Cyn Rd	767,193	Large Drainage Area

6.0 PROPOSED IMPROVEMENTS

Following the assessment of the City's storm drain infrastructure for the existing condition, a process was developed to systematically audit individual City assets and propose upgrades and additions to the network. The performance criteria for the 100-year, 24-hour storm event was used to determine if the intended level of service was being met and where upgrades and network additions were required.

6.1 PROPOSED IMPROVEMENT TYPES

The following section provides the suite of solutions proposed to mitigate flooding and improve the City stormwater conveyance system to meet requisite levels of service. Solutions were focused on upsizing existing infrastructure, including pipes, inlets and detention facilities, and the addition of new conveyance/inlets where existing inlets/conveyance were overwhelmed.

6.1.1 Inlet Improvements

In areas where an inlet is undersized, and stormwater is unable to sufficiently enter the storm drain network, a varying combination of a larger inlet and/or an additional upstream inlet was proposed to alleviate the overwhelmed infrastructure. In all cases, the proposed inlet type was a curb opening inlet. In cases where existing inlet capacity was determined to be insufficient, a field survey should be completed to verify whether the modeled configuration is appropriate (e.g., where existing data were not provided in the GIS or as-builts).

6.1.2 Pipe Infrastructure Improvements

In locations where modeled upstream flooding indicated the appropriate solution is a larger diameter conduit or a new length of pipe, a catalog of standard sizes from the County Local Drainage Manual was applied (18 to 72 inches in increments of 3 inches, and 72 to 104 inches in increments of 6 inches).

Note that where pipe infrastructure improvements are identified as necessary to mitigate flooding, a survey or field assessment is recommended to verify existing pipe diameters if that data was unknown or unavailable in the data provided.

6.1.3 Culvert Improvements

Culvert improvements are similar to pipe infrastructure improvements in that they necessitate upsizing of existing infrastructure to effectively convey flooding. However, they do represent a separate class of improvements that carries with it differences in risk, cost, construction management, and associated level of service. Culverts convey runoff underneath roadways perpendicular to the direction of travel, so any flooding occurring at these locations has the potential to fully block traffic. Additionally, flooding can increase or exacerbate infrastructure degradation if flooding continues to occur at the identified location.

6.1.4 Surface Detention Storage

Some locations require additional storage of runoff to provide adequate flooding protection due to the timing and magnitude of surface runoff that cannot be feasibly captured by inlet or pipe improvements. For these cases, the use of subsurface storage vaults, infiltration galleries, or modular wetland systems is recommended; the ultimate storage type depends on site-specific conditions and constraints. These stormwater BMPs capture and store water, treating it via filtration, and release it either back to the system at a much lower flowrate or to groundwater storages by way of infiltration. Figure 6-1 shows an example of a modular wetland system that uses subsurface storage, filtration media, and surface plantings to capture and treat stormwater and provide the drainage system the slack it needs to convey flows without surface flooding. A variety of types of storage systems is available, and each of these types can be custom designed to fit a variety of conditions and site requirements.

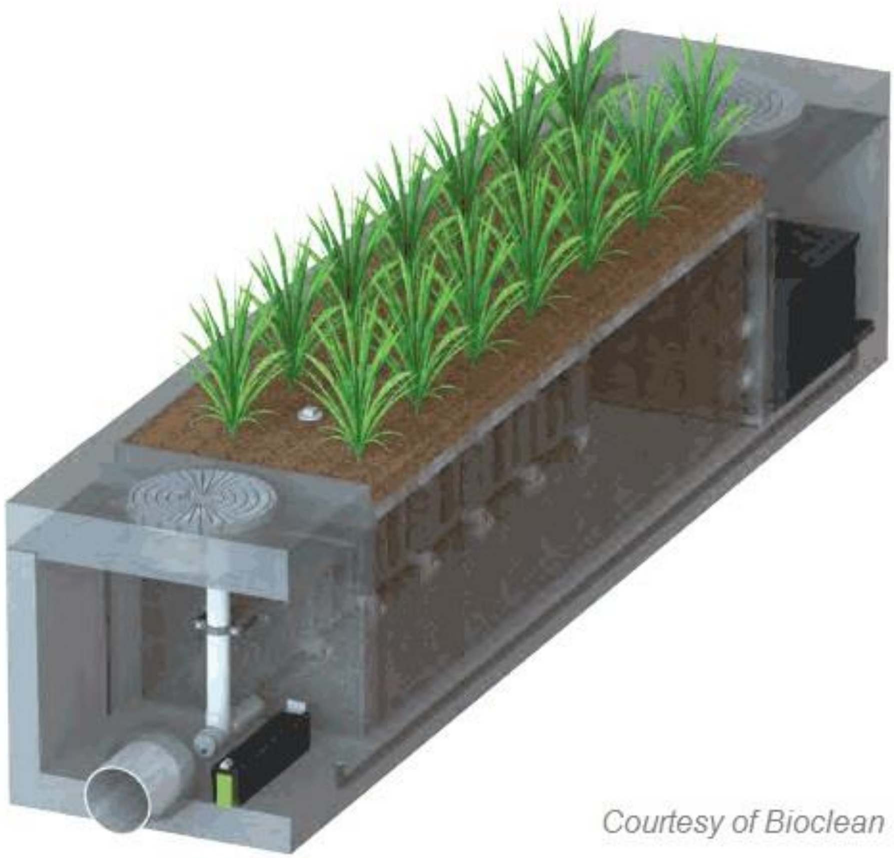

Figure 6-1. Example modular wetland system providing storage for surface runoff

6.2 PROPOSED IMPROVEMENT METHODOLOGY

The stepwise methodology of increasing capacity in the storm drain network was executed and the proposed storm drain system recommendations were simulated to demonstrate how flood control levels of service could potentially be met across the City. This section summarizes the improvements recommended for City conduits, inlets, and storages. Considerations were made within this methodology to consider cost, ease of implementation, coordination with City staff, and other criteria already identified in this report. Proposed improvements included both grey (hard infrastructure improvements only) and green infrastructure (more natural stormwater solutions) options. Final recommendations were screened by City staff through coordination meetings to ensure the best options for the City were ultimately included. These ultimate recommendations were guided by realistic City-specific project knowledge, feasibility, and cost.

6.2.1 Hierarchy of Improvements

A systematic approach was taken to determine the simplest solution to ensure that proposed improvements would effectively manage flooded runoff volumes to the required level of service for the associated infrastructure. This methodology was developed based on knowledge of the reasons for flooding at different locations in the drainage system, whether associated with hydrologic or hydraulic capacity in the system. This methodology followed the following logic:

If surface flooding occurred in the existing condition model at an inlet in the system without any associated hydraulic surcharging:

1. The inlet was upsized. However, if sufficient inlet geometry to abate flooding was not feasible, then
2. A new inlet and pipe length were added upstream of the flooded inlet location if the upstream drainage area was greater than 10 acres. However, if flooding was still not fixed, then
3. Subsurface storage was added upstream of the inlet to capture excess flooding that the inlets could not sufficiently accommodate.

If flooding was associated with hydraulic surcharging,

1. The associated pipe length with a jump in hydraulic grade line (HGL) was identified. This point indicates a constriction in the system, so the associated pipe was incrementally upsized, and the model was rerun to determine if the larger pipe could convey the flooded volume. If this was not possible after increasing the size of a reasonable length of pipe (< 1000 feet), then
2. Subsurface storage was added upstream of the inlets to the identified pipe to capture enough stormwater so that flows could be conveyed along the upsized pipe.

6.3 PROPOSED IMPROVEMENT RESULTS

The improvement methodology outlined above was used to identify the simplest solution to effectively manage flood volumes. These recommended improvements differ by type and vary in scope, cost, and scale of improvement needed. They are summarized below based on the type of infrastructure the improvements are associated with.

6.3.1 Inlet Improvements

Flow into inlets is dependent on the depth of water at the inlet, inlet type and size. To address flooding in the existing conditions model, inlet capacity was increased at 11 inlets; 8 existing inlets were upsized, and 3 new inlets were added to address local flooding. See Appendix D for detailed exhibits for the locations of these proposed inlet improvements.

6.3.2 Pipe Improvements

To improve conveyance capacity throughout the City, City-owned conduits were upsized incrementally to common pipe sizes to identify the smallest proposed pipe size along the shortest length of pipe that would meet the 100-yr performance criteria at upstream locations. Throughout the City, approximately 2,476 feet of upsized pipe have been proposed to meet the demands of the 100-year storm runoff flows and volumes. Sixteen locations have been identified for these proposed infrastructure improvements. Most of these locations require increasing the pipe diameter by 6 inches. There were 3 locations where a 9-inch increase was warranted, and 2 locations that required an increase of 1-foot in diameter.

Additionally, new storm lines were added to the City infrastructure to connect new inlets (3, as mentioned previously) to the existing storm drain network. A total of 1,757 feet of new conduits were proposed and sized to provide additional capacity to the system in large drainage areas without infrastructure. Most of this proposed new conduit would need to be 18 inches in diameter (87% of new conduit length), with the remainder sized to 36 inches. In total, 0.8 miles of City conduits were improved or added to allow conveyance of the 100-year storm event. See Appendix B for detailed exhibits of where conduit improvements were proposed, and Appendix C for a detailed table of model and costing results for each proposed conduit improvement.

6.3.3 Culvert Improvements

As mentioned above, culvert improvements are very similar to pipe improvements in that they require upsizing the existing infrastructure to effectively convey flooding. Culvert improvements were evaluated as such by systematically upsizing existing culverts until the flows were sufficiently conveyed without causing flooding across the roadway. Culvert upsizing was proposed at 5 locations, with 3 of these (on S Alisal Rd) requiring an upsize of 6 inches from existing pipe size over a total length of 125 feet. Two locations required a doubling in size (Fredensborg Canyon Rd) where flooding has been noted and is due to a larger drainage area draining to an ephemeral stream course. At this location it is proposed that the existing 48-inch culverts be upsized to 96 inches (over 114 feet) due to the high runoff collecting at these roadways. See Appendix B for detailed exhibits for where these culvert improvements are proposed.

6.3.4 Subsurface Storages

Subsurface storage BMPs were incorporated upstream of the inlet where flooding was shown to occur to alleviate flooding where additional storage was required. Storage BMPs were sized to sufficiently capture the flooding volume at these locations to optimize their effectiveness for flood protection. These BMPs were modeled to provide peak flow protection as opposed to capture of the full event runoff. Two subsurface storages were proposed to capture approximately 11,000 cubic feet of flood runoff. See Appendix B for detailed exhibits for where these subsurface storages were proposed.

6.4 PROPOSED IMPROVEMENT COSTING

Planning level cost estimates were developed for the proposed changes to the system. The costs provide an estimate of what type of funding would be needed to fully address flooding concerns identified in the existing conditions model. This master plan serves as a high-level project planning document. The calculated project costs have the following limitations:

- Impacts to existing infrastructure in the project area are not included in costs;
- Costs are calculated from regional unit costs and not determined on a site or project basis; and
- Costs are calculated as if each was a stand-alone project. It is recommended that in future requests for proposal (RFPs) projects are grouped by site to reduce mobilization, planning, and traffic control costs.

These costs account for the full range of project costs covering materials & construction, design & planning, permitting, project management, mobilization, and contingency. Unit costs for the different project components were developed from a range of the most applicable sources including recent bids submitted to the City, RS Means construction costing software for Santa Barbara County (2018), Caltrans Santa Barbara cost data, and previous Tetra Tech stormwater project data in California. Table 6-1 shows the improvement project costs grouped by proposed improvement type and overall for the full system-wide improvements. Table 7-2 details location-specific improvements and costs. See Appendix C for detailed costing breakdowns of each individual proposed improvement.

Table 6-1. Summary of proposed improvements costs

Item	Number of Projects	Cost
Inlet Improvements	11	$413,500
Pipe Improvements	19	$3,002,300
Culvert Improvements	5	$578,500
Subsurface Storages	2	$445,100
Total	**37**	**$4,439,400**

Table 6-2. Proposed improvements and cost estimates by location

Location	Proposed Solution	Cost Estimate
Alisal Rd & Juniper Ave	Upsize Pipe Segments	$781,700
Chalk Hill & Fredensborg Cyn Rd	Upsize Pipe Segments	$168,400
Copenhagen Dr & 2nd St	Upsize Pipe Segments, Upsize Inlets	$996,100
Coyote Creek Rd	Add Inlet and Connector Pipe, Upsize Pipe	$214,000
Elverhoy Way & 3rd St	Upsize Inlet	$21,700
Maple Ave & Pine St	Extend Pipe to Outfall, Add inlet	$300,400
Mission Dr & 4th Pl	Upsize Pipe Segments, Upsize Inlet, Add Distributed Subsurface Storage	$820,300
South Alisal Rd	Upsize Culverts	$188,900
Viborg Rd	Upsize Inlet and Connector Pipe	$194,300
Viborg Rd & Alamo Pintado Rd	Add Inlet and Connector Pipe, Upsize Inlets	$314,600
West Chalk Hill Rd	Upsize Inlet	$49,400
Fredensborg Cyn Rd	Upsize Culverts	$389,600

7.0 PRIORITIZATION FRAMEWORK

While full knowledge of the improvements needed for the system to provide the necessary level of service is invaluable, having a way to prioritize these improvements is also necessary for the City. Planning, funding, construction, and ongoing maintenance are key components of system improvements. It is infeasible to undertake all projects at once. A prioritization framework offers the City a means to determine when certain projects should be undertaken by assessing the critical nature of each of the recommended improvements as well as how project implementation fits into other aspects of City management and development. A risk-based approach, which also accounts for additional City-identified factors, was taken to provide a clear pathway to implement the proposed improvements. The approach accounts for the risk involved with asset vulnerability to flooding as well as other important factors for the City in carrying out these projects.

Projects were scored based on a Business Risk Exposure (BRE) calculation. This type of prioritization allows for identification of projects that will mitigate the greatest risk to the City. To calculate risk, the probability of failure (i.e. severity of flooding & pipe condition; POF) is multiplied by the consequence of failure (i.e. location of flooding; COF) as shown in the equation:

$$BRE = POF * COF$$

Since recognizing that there may be other factors that the City would like to use to prioritize projects, additional criteria were incorporated based on City preferences. The criteria were then summed and added to the BRE score to produce a total score as shown in the equation:

$$Total\ Score = BRE + \sum Additional\ Criteria$$

Additional criteria were developed in conjunction with City managers to align project scoring with points of focus for ongoing efforts and emphases within City programs and future planning. These included the potential for funding through grants, ease of implementation and maintenance, regulatory compliance addressed by the project, and a project's potential for bundling with other improvements as well as coordination with future development. The additional criteria and those assessed for POF and COF scores can be found in Table 7-1 along with detailed scoring for each of the proposed improvements.

Table 7-1. Project Prioritization Framework – POF scoring criteria

POF Criteria	Scoring Rubric
Capacity	Value assigned from 1-5 based on a sequential ranking of project areas based on flooded volumes
Condition	Value 0 applied if no CMP replacement was designated for the project area, 5 applied if CMP replacement was present
TOTAL	***Maximum of the capacity and condition POF values***

Table 7-2. Project Prioritization Framework - COF scoring criteria

COF Criteria	Scoring Rubric
COF by Land Use	Value assigned from 1-5 based on primary adjacent land use to location of flooding
COF by adjacent Road Type	Value assigned from 1-5 based on primary adjacent road type to location of flooding
TOTAL	***Sum of land use and road type COF values***

Table 7-3. Project Prioritization Framework - Additional Criteria scoring

Additional Criteria	Scoring Rubric
Grant Opportunity Project	Value of 3 added if project includes green infrastructure
Ease of Implementation/Permitting	Values added for projects that have low permitting and implementation requirements • 5 added for inlet improvements • 3 added for pipe improvements • 1 added for bundled inlet and pipe improvements
Regulatory Compliance – Trash Capture	Value of 5 added if trash capture component can be added easily to project
Ease of Maintenance	Value of 3 added if project requires low ongoing operations and maintenance resources
Potential Coordination w/ Future Development	Value of 3 added if project has potential to be combined with future planned development
Stormwater Improvement Bundled Project	Value of 2 added if project bundled with multiple flooding improvements
Non-stormwater CIP Bundled Project	Value of 1 added if project bundled with a non-stormwater capital improvement
TOTAL	***Sum of Additional Criteria values***

8.0 PRIORITIZED CIP PROJECTS

Table 8-1 summarizes the results of the prioritization framework with BRE scores (with and without additional criteria) as well as estimated improvement project costs. Improvement projects do not rank identically between the two BRE scoring metrics, but it should be noted that the 5 highest scoring projects are consistent between the two. This is important to note as it indicates that the additional criteria included do not affect the prioritization order of the projects with the highest associated risk. Project prioritization scores are mostly stratified between higher and lower risk, with the five highest scoring projects clearly indicating priority over others. The projects have been grouped into three categories based on the proposed implementation timeline. **Dark green** indicates projects recommended for the initial phase of implementation, **medium green** highlights projects for the second phase, and light green are for the final implementation phase. Note that the three culvert improvements proposed for South Alisal Road are split into two phases based on the planned implementation timeline related to available funding. There is currently a road realignment and bike sharing project proposed for South Alisal. As part of the bid for this project, improvement of the culvert with the greatest flooding, SDCW045, will be included. Upsizing of the other two culverts will be completed at a later date as funding permits.

Table 8-1. Project prioritization scores summarized with estimated cost

Project Name	Project Type				BRE	BRE w/ Criteria	Cost
	Pipe	Inlet	Culvert	Storage			
Copenhagen & 2nd	X	X			39.00	53.00	$ 996,100
Mission Dr & 4th Place	X	X		X	36.00	46.00	$820,300
Viborg Rd & Alamo Pintado	X	X			27.00	33.00	$314,600
Maple & Pine	X	X			18.67	27.67	$300,400
S Alisal Rd **Phase 1 -** SDCW045 **Phase 2 -** SDCW046 & SDCW029			X		16.67	26.67	Phase 1 $52,900 Phase 2 $136,00
Chalk Hill & Fredensborg Cyn Rd	X				20.00	26.00	$168,400
Fredensborg Cyn Rd			X		20.00	23.00	$389,600
Alisal Rd & Juniper Ave	X				13.33	22.33	$781,700
Coyote Creek Rd	X	X			11.00	17.00	$214,000
Viborg Rd	X	X			9.33	15.33	$194,300
Elverhoy & 3rd		X			5.33	13.33	$21,700
West Chalk Hill Rd		X			5.00	13.00	$49,400

Considering cost alongside the BRE scores adds a mechanism for further project prioritization. The City can use this information to help gage the funding necessary to tackle the highest risk projects as well as what funding sources might be best utilized and/or sought for these improvements. For example, the proposed inlet improvement at Elverhoy and 3rd Street is the lowest cost project. As a result, it is likely that implementation of this improvement is prioritized based on available funds for capital improvement projects. Figure 8-1 demonstrates how the proposed improvements are distributed along both prioritization scoring as well as estimated project cost. They are distributed among areas of the plot that are associated with higher or lower risk and higher or lower cost. This information can be used to further tailor project prioritization by the City that is in line with available sources of funding and project implementation capacity moving forward. Emphasis on prioritization would be placed on risk, but this could be evaluated relative to other projects and available funding sources so that progress in making improvements is not necessarily hampered solely by funding mechanisms. In this way, the most cost-effectively improvable risks in system level of service can be improved more quickly while larger sources of funding for additional higher-cost high-risk projects is secured.

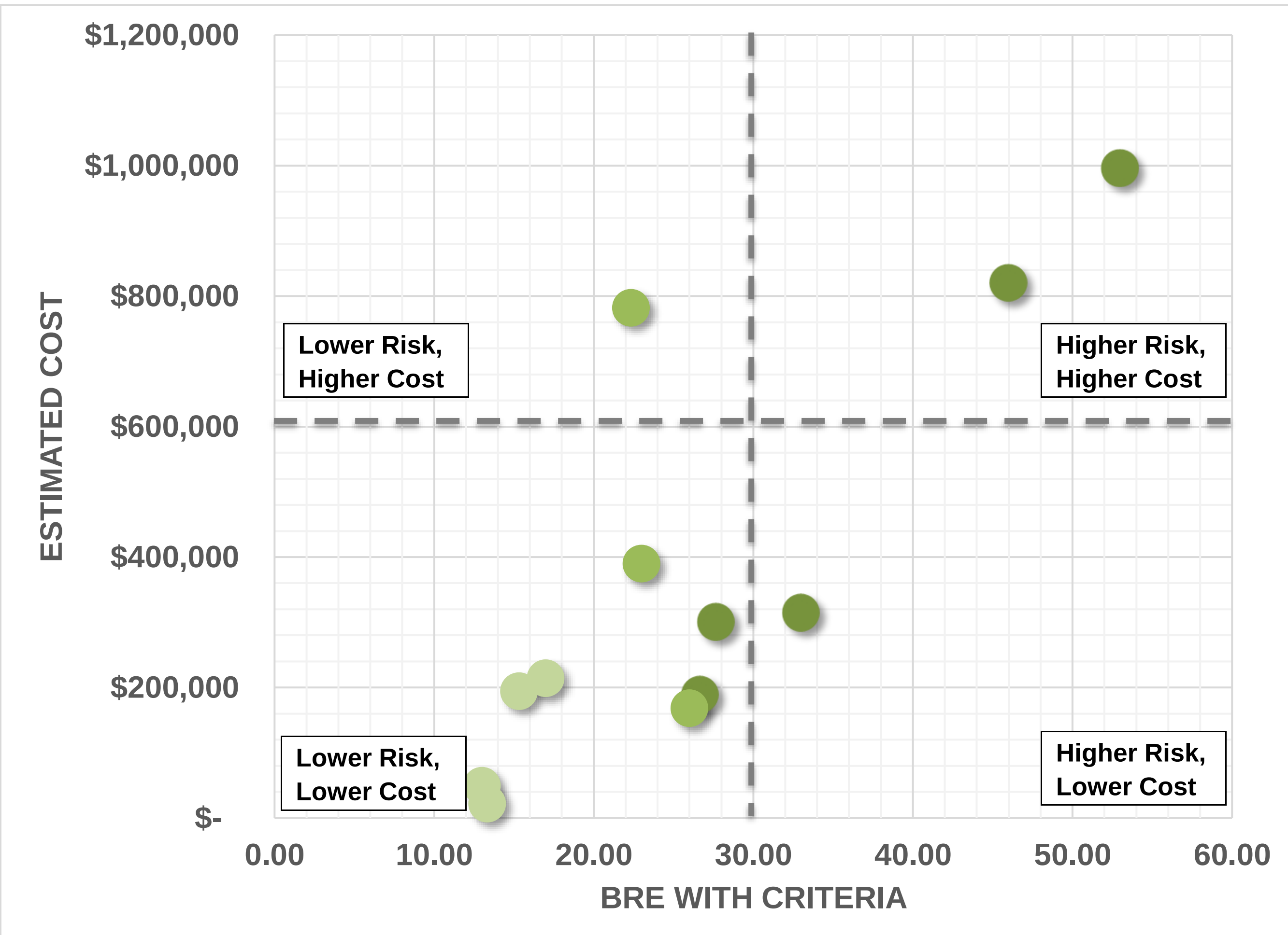

Figure 8-1. Plot of prioritization scores versus estimated costs

9.0 FUTURE RECOMMENDATIONS

While the SSMP provides clear identification of deficiencies in the system to meet the current level of service, characterization of proposed improvements, and how the improvements should be prioritized by the City, there are additional recommendations that could benefit the City to maximize return on investment. The following recommendations will enhance the knowledge of the system, provide guidance for managing the system in the context of regulatory requirements, and highlight how the system can be maintained to ensure continuing levels of service that will contribute to City-wide drainage and improved watershed conditions in an efficient and effective manner.

9.1 TRASH CAPTURE DEVICE SIZING

To comply with the Statewide Trash Amendments, the City of Solvang has chosen to pursue Track 1 implementation. Track 1 compliance requires the City to install, operate, and maintain full capture systems in all storm drains that capture runoff from a priority land use in their jurisdiction. As part of their implementation plan, the City has developed a map locating the full capture device locations and types. Prior to implementation, the City will need to analyze the site and device constraints and determine suitable full capture devices for each of the locations identified. The analysis could employ the fully articulated storm drain system modeled in PCSWMM for the SSMP to determine the flow to inlets and outfalls identified for trash capture implementation. The results could inform the appropriate selection and sizing of full capture systems throughout the City.

9.2 SYSTEM CONDITION ASSESSMENT

An assessment of the current system conditions may be warranted to most effectively manage the City's stormwater system. The modeling included in the SSMP looks at system capacity, but an ongoing management need for stormwater infrastructure is ensuring that these assets are still fully-functional. Because stormwater pipes degrade over time, it is crucial to fully understand the life cycle of these assets to schedule regular replacement as needed and to strategically coordinate with other improvements at the same time (e.g., road pavement, utility maintenance, etc.). A system to track asset characteristics, condition, maintenance activities, and other relevant data could drive City-wide asset management. Given a lack of data related to current infrastructure condition, a plan to assess system-wide conditions and establish a baseline for future management could be accomplished through records review, inspections of the full system, or potentially using proxy data from a small subset of inspections to predict conditions City-wide using a geospatial analysis.

9.3 COMPREHENSIVE CIP PLANNING

The prioritization of recommended projects within the SSMP was focused on flood-related levels of service; however, the prioritization could be expanded to include the results of the recommended system condition assessment, trash capture implementation plans, the City's CMP replacement strategy, and other CIP planning. All of these efforts could be incorporated into the stormwater CIP framework for a comprehensive assessment and prioritization plan for all City stormwater system efforts. This would provide assurance that all efforts are coordinated and accounted for to enable comprehensive planning. Additionally, developing monitoring plans and system tracking provides invaluable information that can be used to adapt models, revise plans, and regularly update project prioritization in a reflexive manner to guide system management activities in the most informative and concerted way possible.

9.4 MAINTENANCE PLANS

As proposed improvements identified in the SSMP move from planning to construction, it is recommended that maintenance plans are developed for these new projects. Maintenance plans will help position future resources and activities and ensure the full lifespan and functionality of green and grey infrastructure projects. These plans should consider schedules of required maintenance activities, expertise required, costs, and specific actions needed to ensure the full functionality of these stormwater system components. Maintenance plans could also be developed for other existing assets using the results of the recommended system condition assessment as a baseline for maintenance needs and requirements. Maintenance plans ensure longevity of the stormwater system components and realization of the flood control and water quality benefits they are designed to provide. O&M plans can be integrated into the aforementioned comprehensive CIP plan to help account for the true system costs.

10.0 REFERENCES

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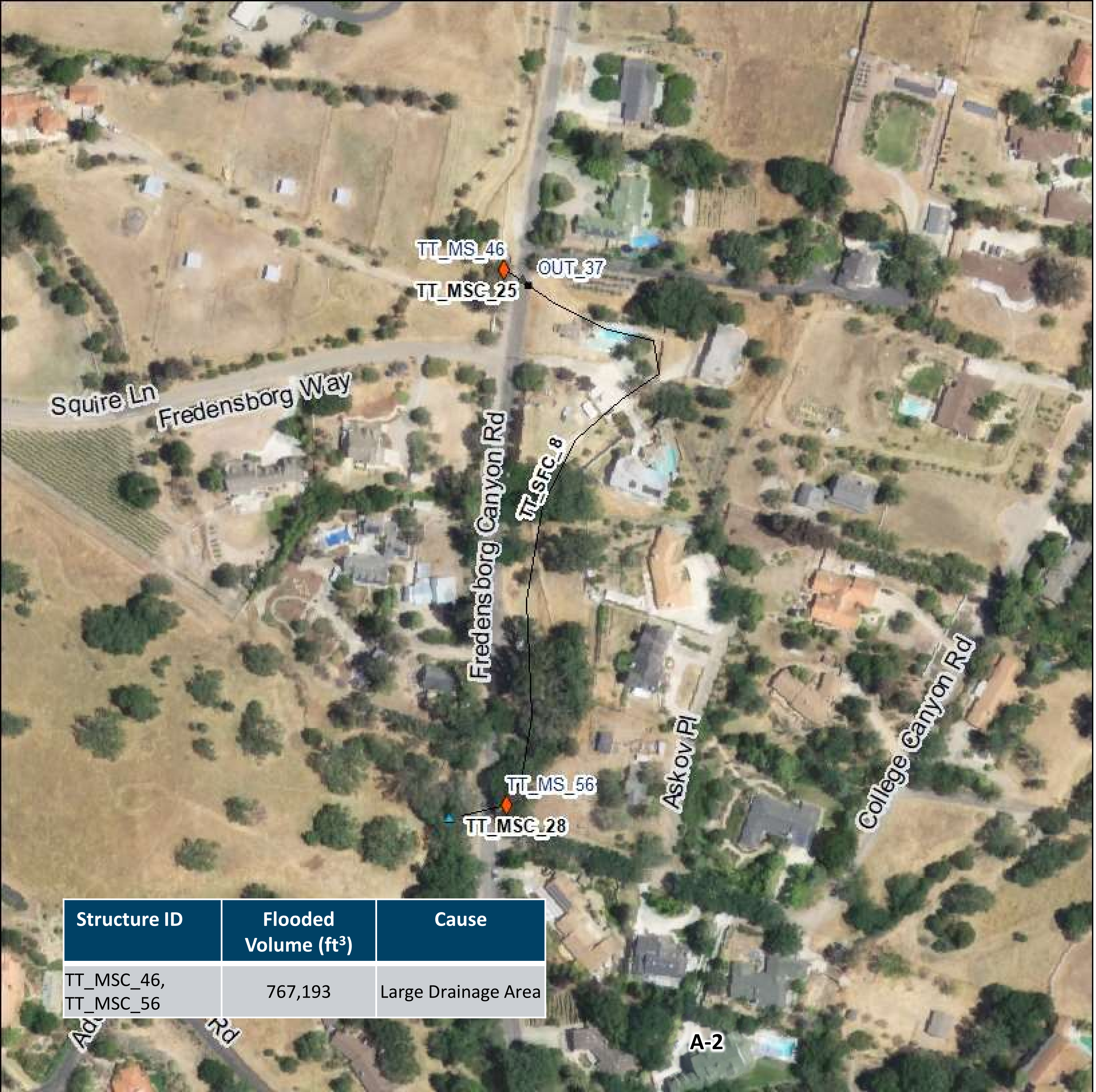
APPENDIX A: EXISTING CONDITION MAPS

Solvang Master Plan
Fredensborg Canyon Rd



Structure ID	Flooded Volume (ft³)	Cause
TT_MSC_46, TT_MSC_56	767,193	Large Drainage Area

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure

- No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

Cause of Flooding at Structure

- Large drainage area
- Storage capacity
- Inlet capacity
- Pipe capacity

Public Structure

Private Structure

Caltrans Structure

- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

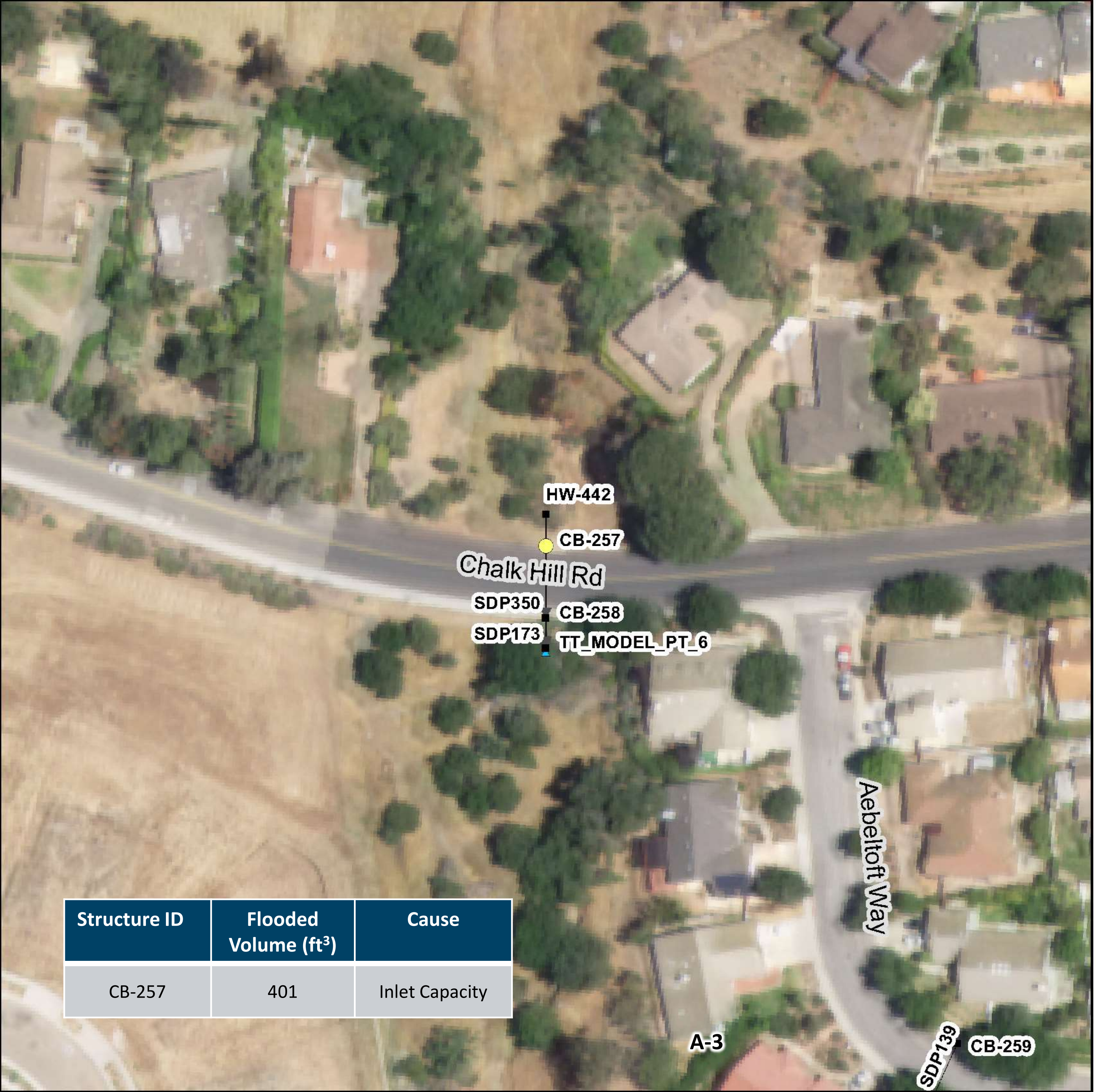
TETRA TECH

The City of SOLVANG Danish Capital of America

N

0 110 220 Feet

Solvang Master Plan
West Chalk Hill Road



Structure ID	Flooded Volume (ft^3)	Cause
CB-257	401	Inlet Capacity

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure
- No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

Cause of Flooding at Structure
- Large drainage area
- Storage capacity
- Inlet capacity
- Pipe capacity

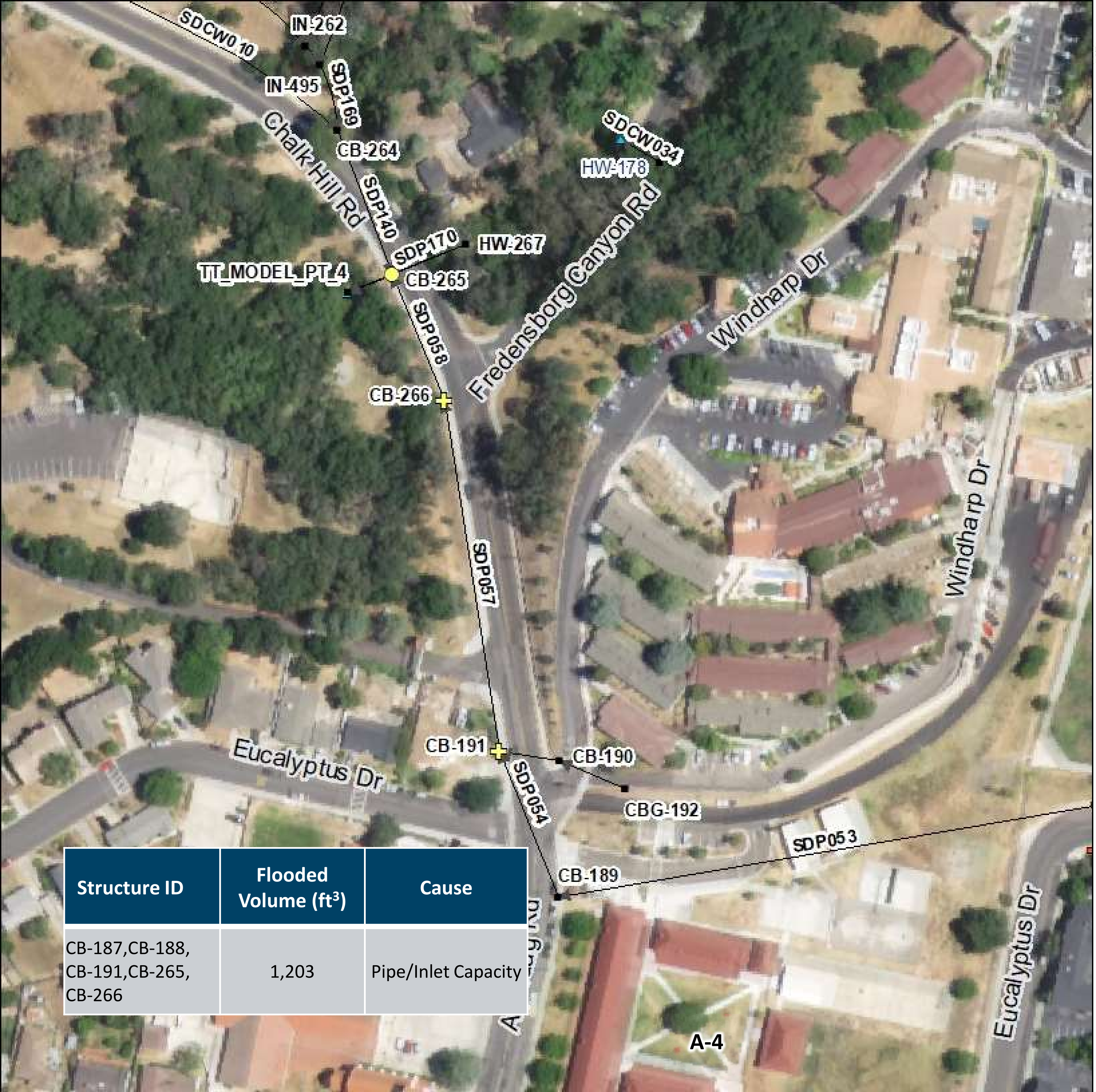
Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH
The City of SOLVANG Danish Capital of America

N
0 50 100 Feet

Solvang Master Plan
Chalk Hill & Fredensborg Canyon Rd



Structure ID	Flooded Volume (ft^3)	Cause
CB-187,CB-188, CB-191,CB-265, CB-266	1,203	Pipe/Inlet Capacity

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure
- ■ No Flooding
- ● Low Flooding (< 1.5 ft)
- ● High Flooding (> 1.5 ft)

Cause of Flooding at Structure
- ◊ Large drainage area
- □ Storage capacity
- ○ Inlet capacity
- ✣ Pipe capacity

Public Structure
Private Structure
Caltrans Structure
▲ Outfalls
→ Conveyance
Inlet Drainage Area

Vicinity Map

TETRA TECH
The City of SOLVANG Danish Capital of America

N
0 80 160 Feet

Solvang Master Plan
Mission Dr & 4th Place

Structure ID	Flooded Volume (ft³)	Cause
CB-279,CB-421, 4102932001001, 4102932001004, 4102932001005, 4102932001006	20,720	Pipe Capacity

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure
- No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

Cause of Flooding at Structure
- Large drainage area
- Storage capacity
- Inlet capacity
- Pipe capacity

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

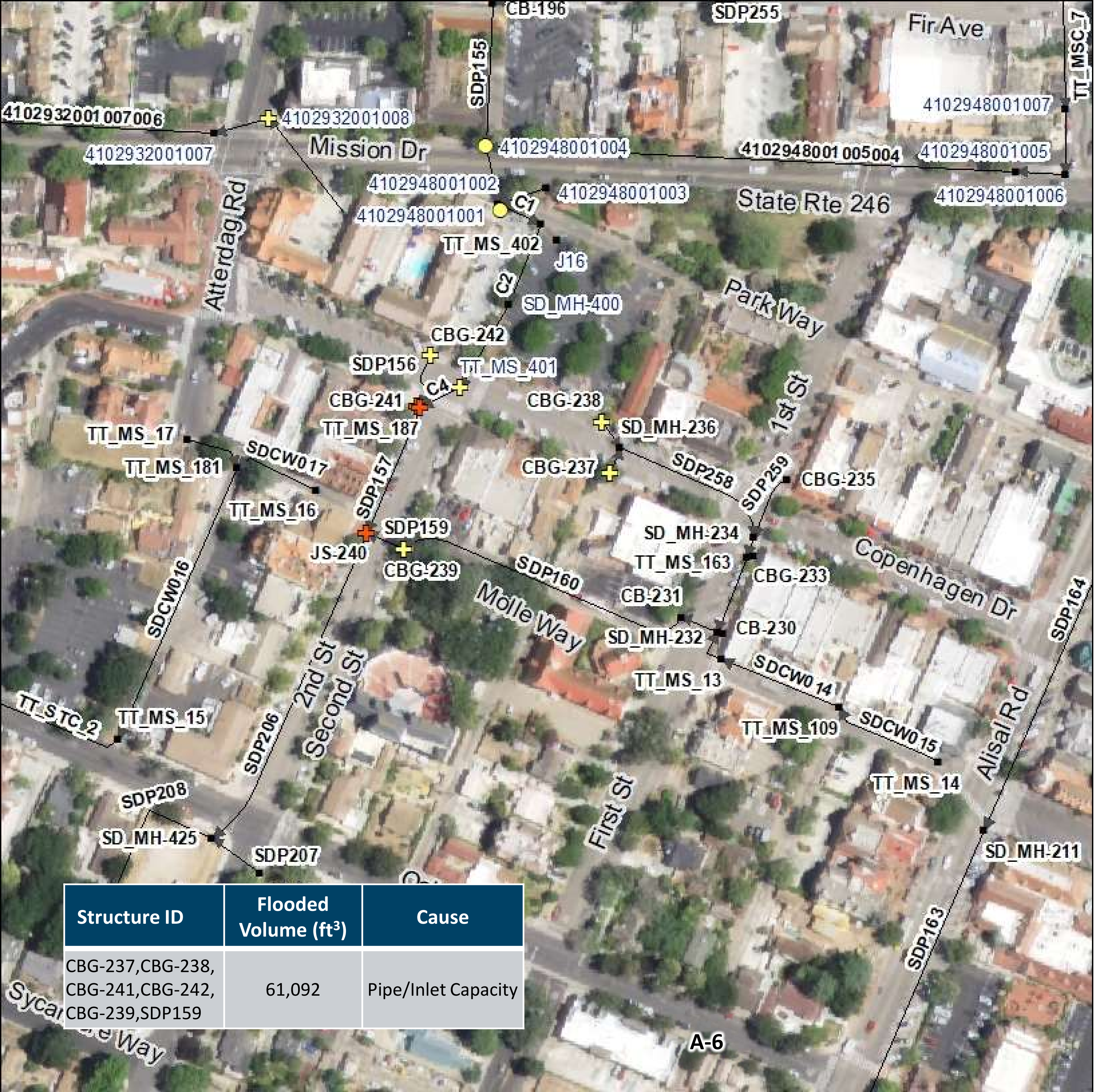
Vicinity Map

TETRA TECH

The City of SOLVANG Danish Capital of America

N

0 100 200 Feet



Solvang Master Plan

Copenhagen Dr & 2nd St

Existing Condition

100-year, 24-hour event

Level of Flooding at Structure

- No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

Cause of Flooding at Structure

- Large drainage area
- Storage capacity
- Inlet capacity
- Pipe capacity

Public Structure

Private Structure

Caltrans Structure

- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

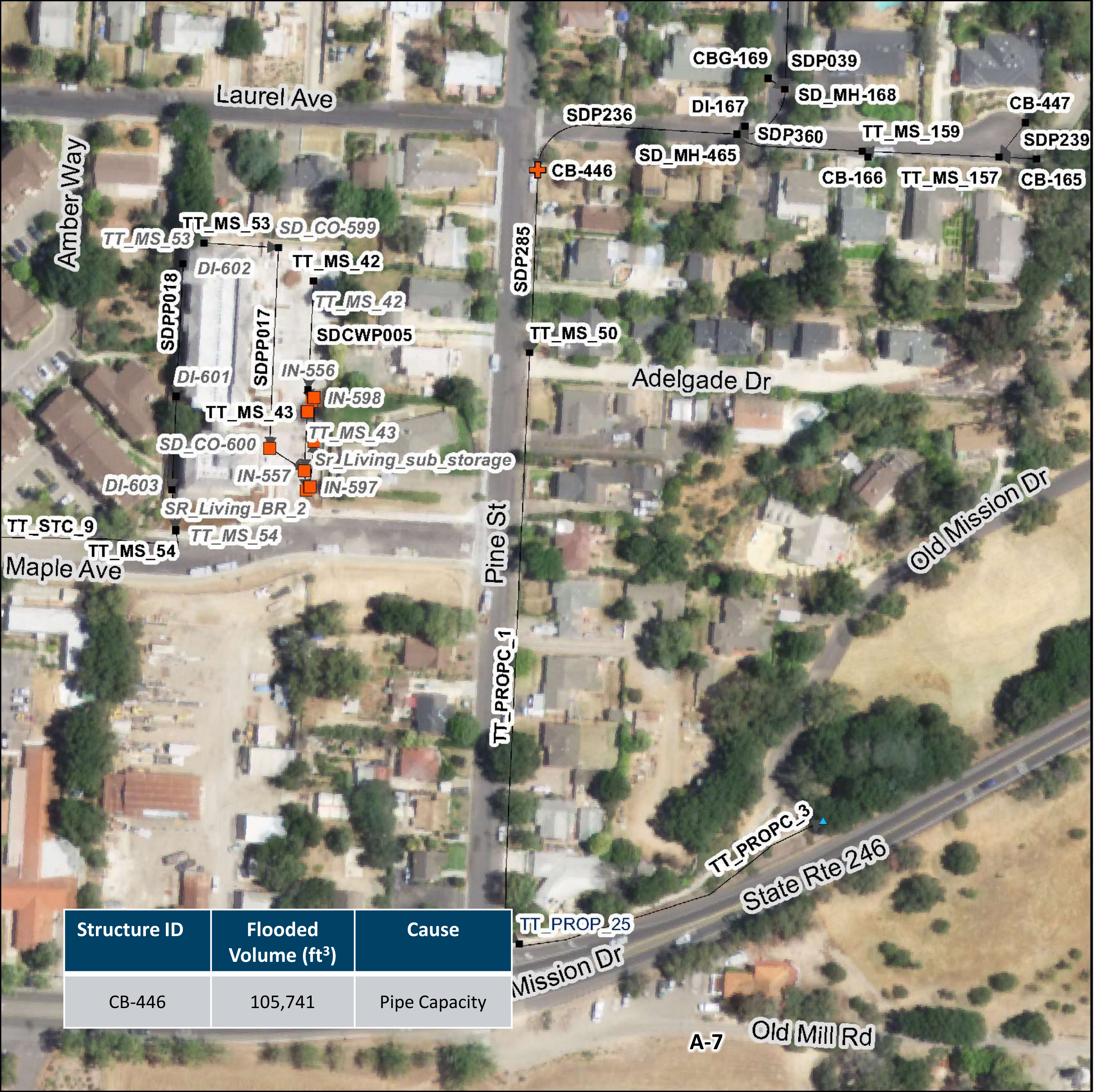
The City of SOLVANG Danish Capital of America

N

0 95 190 Feet

Structure ID	Flooded Volume (ft³)	Cause
CBG-237,CBG-238, CBG-241,CBG-242, CBG-239,SDP159	61,092	Pipe/Inlet Capacity

Solvang Master Plan
Maple Ave & Pine St



Structure ID	Flooded Volume (ft^3)	Cause
CB-446	105,741	Pipe Capacity

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure
- No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

Cause of Flooding at Structure
- Large drainage area
- Storage capacity
- Inlet capacity
- Pipe capacity

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH
The City of SOLVANG Danish Capital of America

N
0 80 160 Feet

Solvang Master Plan
Viborg Rd

Structure ID	Flooded Volume (ft^3)	Cause
CB-145,CB-146	3,075	Inlet Capacity (Large Drainage Area), Pipe Capacity

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure
- ▪ No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

Cause of Flooding at Structure
- ◊ Large drainage area
- ☐ Storage capacity
- ○ Inlet capacity
- ✣ Pipe capacity

Public Structure
Private Structure
Caltrans Structure
- ▲ Outfalls
- → Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

The City of SOLVANG Danish Capital of America

N

0 50 100 Feet

Solvang Master Plan
Viborg Rd & Alamo Pintado Rd

Structure ID	Flooded Volume (ft³)	Cause
CB-111,CB-114, CB-116	7,486	Inlet Capacity (Large Drainage Area)

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure
- No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

Cause of Flooding at Structure
- Large drainage area
- Storage capacity
- Inlet capacity
- Pipe capacity

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

The City of SOLVANG Danish Capital of America

N

0 130 260 Feet

Solvang Master Plan
Coyote Creek Rd

Structure ID	Flooded Volume (ft^3)	Cause
CB-413,CB-459, IN-414,IN-415	11,898	Large Drainage Area

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure
- No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

Cause of Flooding at Structure
- Large drainage area
- Storage capacity
- Inlet capacity
- Pipe capacity

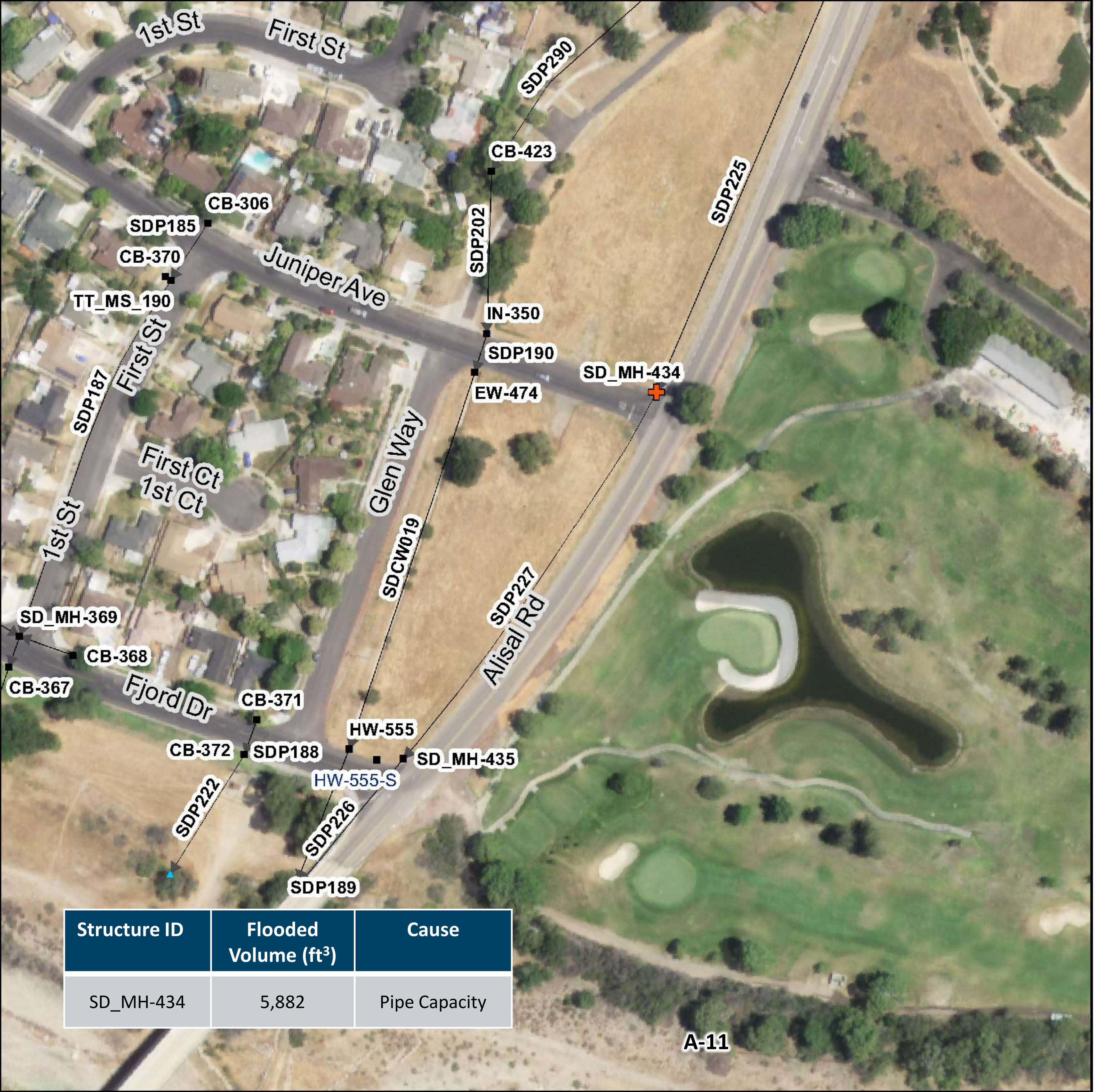
Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH
The City of SOLVANG Danish Capital of America

N
0 87.5 175 Feet

Solvang Master Plan
Alisal Rd & Juniper Ave



Structure ID	Flooded Volume (ft³)	Cause
SD_MH-434	5,882	Pipe Capacity

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure
- No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

Cause of Flooding at Structure
- Large drainage area
- Storage capacity
- Inlet capacity
- Pipe capacity

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

The City of SOLVANG Danish Capital of America

N

0 100 200 Feet

Solvang Master Plan
Elverhoy Way

Existing Condition
100-year, 24-hour event

Structure ID	Flooded Volume (ft^3)	Cause
CB-284	Minor Street Flooding	Inlet Capacity

Vicinity Map

TETRA TECH

The City of SOLVANG Danish Capital of America

N
0 37.5 75 Feet

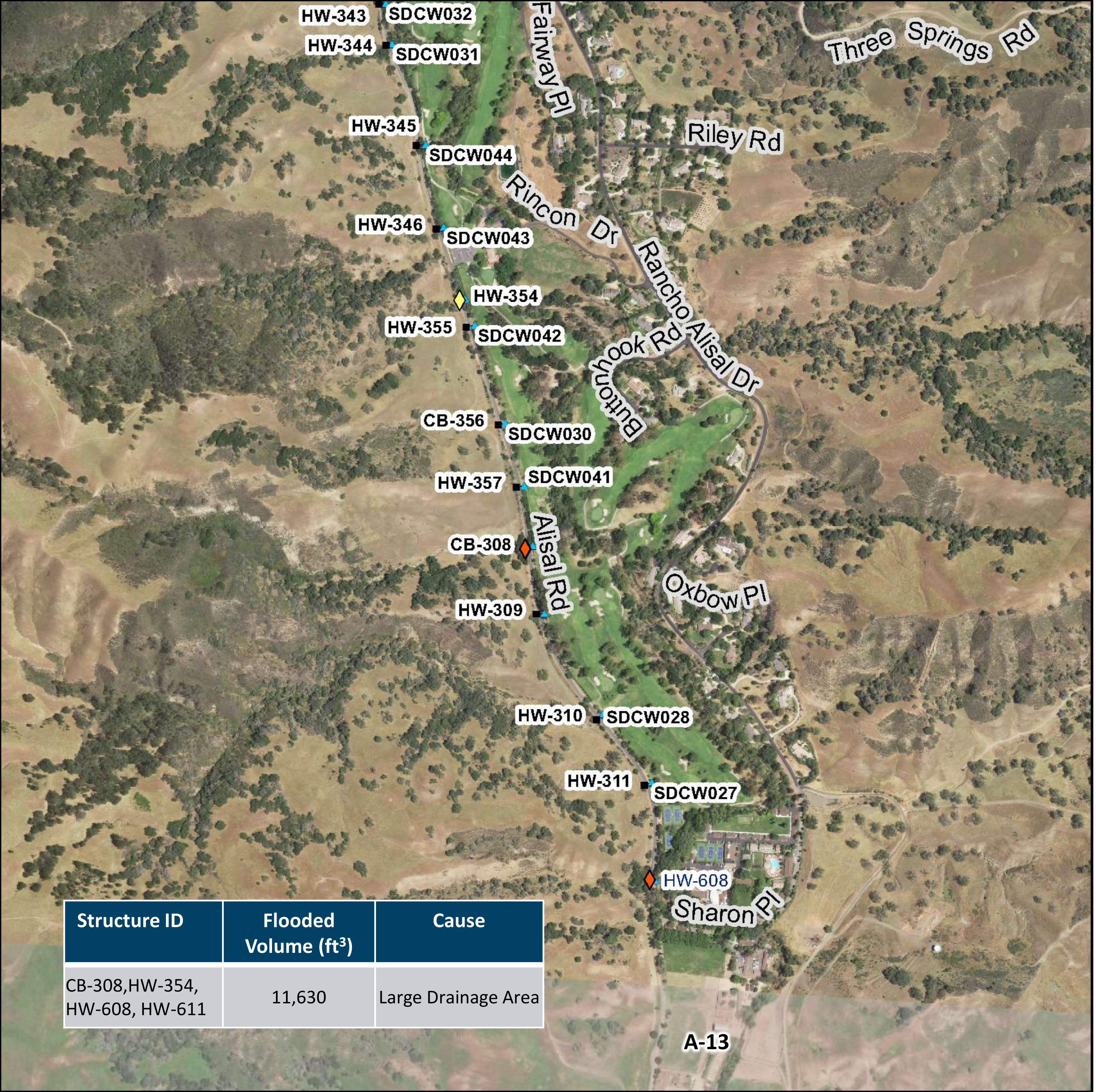
Solvang Master Plan
S Alisal Road

Existing Condition
100-year, 24-hour event

Level of Flooding at Structure
- No Flooding
- Low Flooding (< 1.5 ft)
- High Flooding (> 1.5 ft)

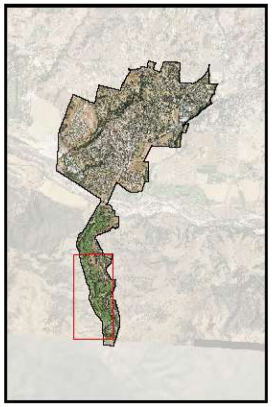
Cause of Flooding at Structure
- Large drainage area
- Storage capacity
- Inlet capacity
- Pipe capacity

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area



Structure ID	Flooded Volume (ft^3)	Cause
CB-308,HW-354, HW-608, HW-611	11,630	Large Drainage Area

Vicinity Map



TETRA TECH
The City of SOLVANG Danish Capital of America

APPENDIX B: PROPOSED CONDITION MAPS

Solvang Master Plan
Fredensborg Canyon Rd

Proposed Condition
100-year, 24-hour event

Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
TT_MSC_46, TT_MSC_56	Upsize Culverts	23.00	$389,600	Phase Two

Proposed Improvements
- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

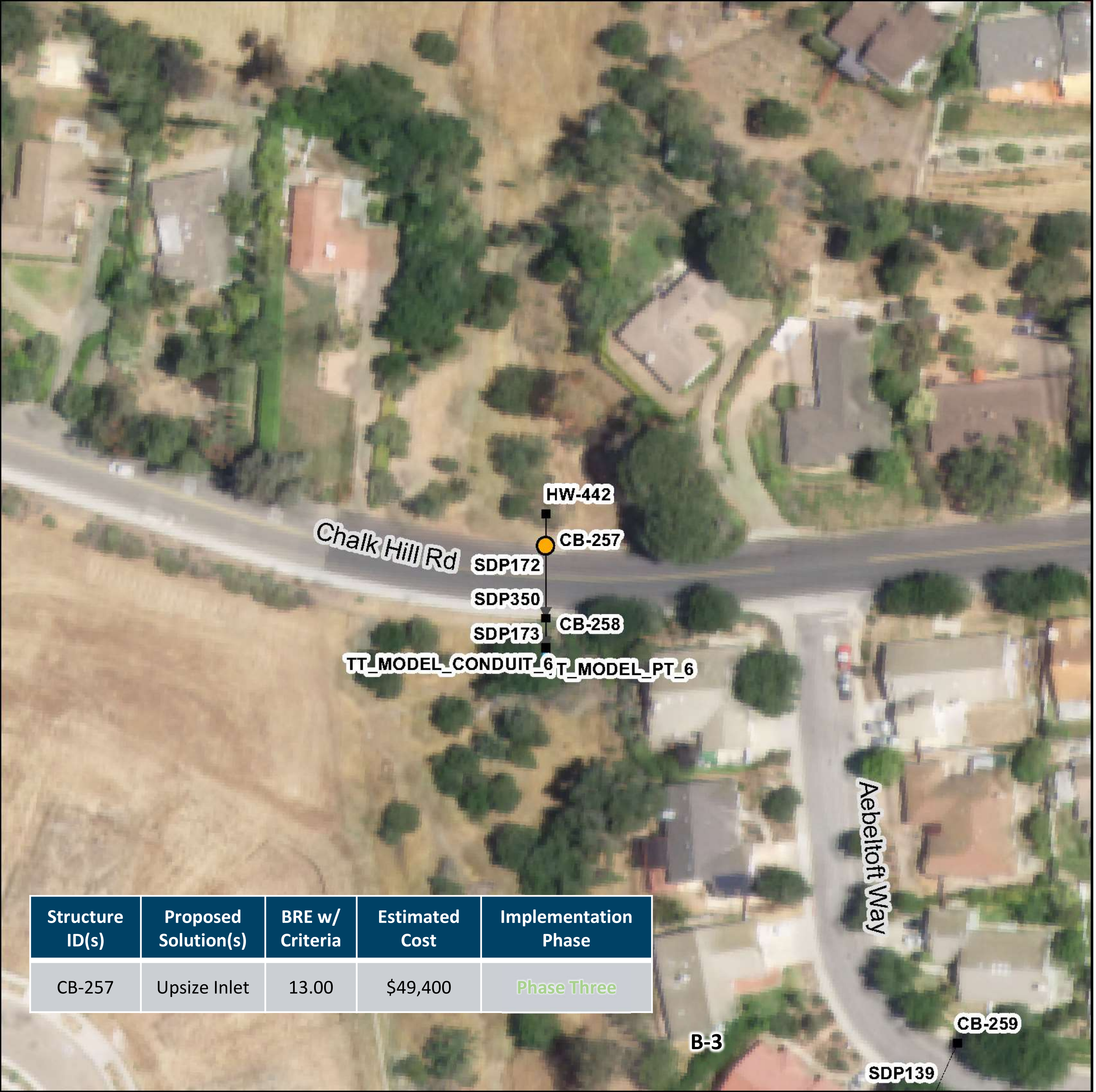
The City of SOLVANG Danish Capital of America

N

0 110 220 Feet

Solvang Master Plan
West Chalk Hill Road

Proposed Condition
100-year, 24-hour event



Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
CB-257	Upsize Inlet	13.00	$49,400	Phase Three

Proposed Improvements

- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure

Private Structure

Caltrans Structure

- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

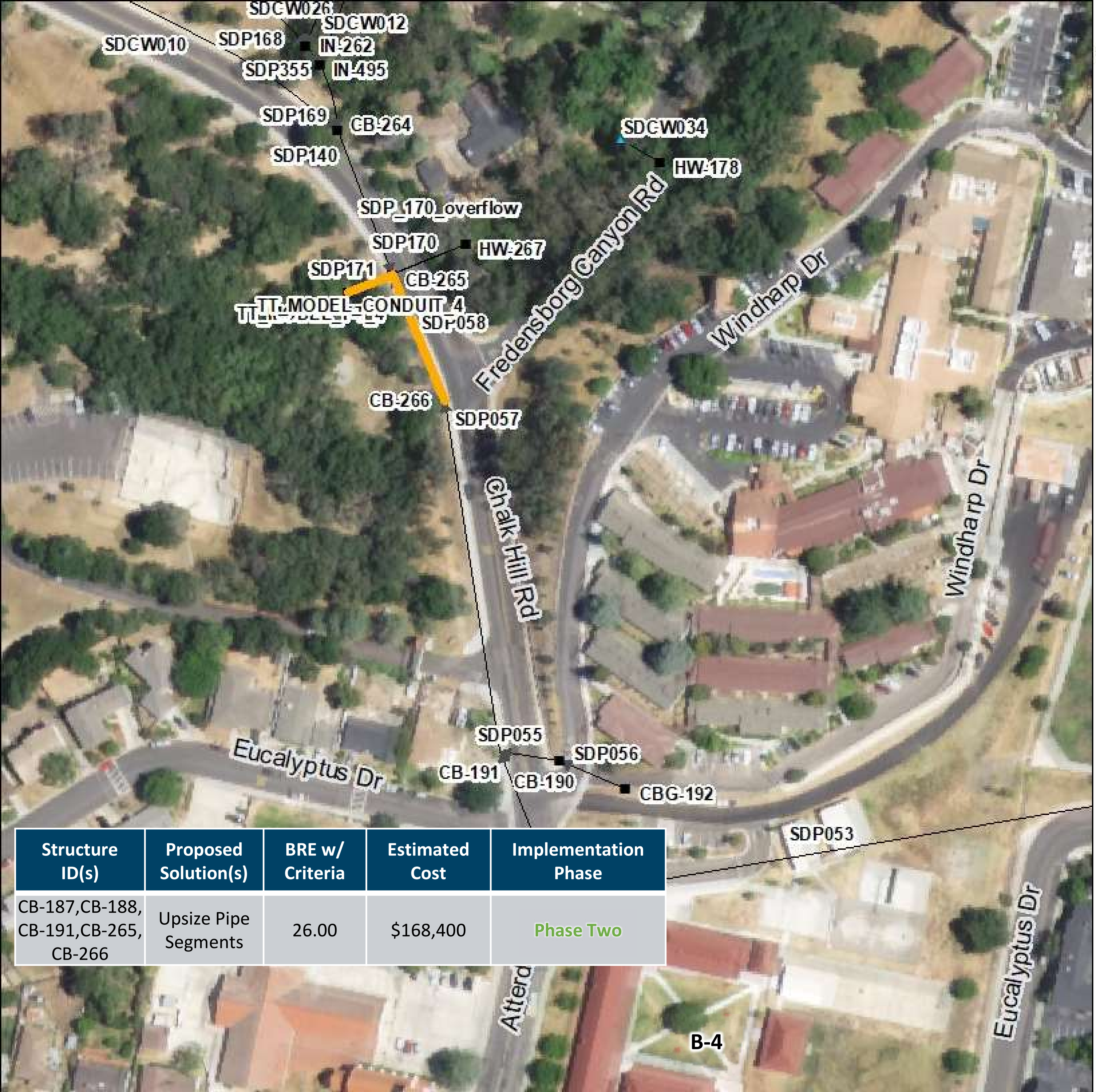
The City of SOLVANG Danish Capital of America

N

0 50 100 Feet

Solvang Master Plan
Chalk Hill & Fredensborg Canyon Rd

Proposed Condition
100-year, 24-hour event



Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
CB-187,CB-188, CB-191,CB-265, CB-266	Upsize Pipe Segments	26.00	$168,400	Phase Two

Proposed Improvements
- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

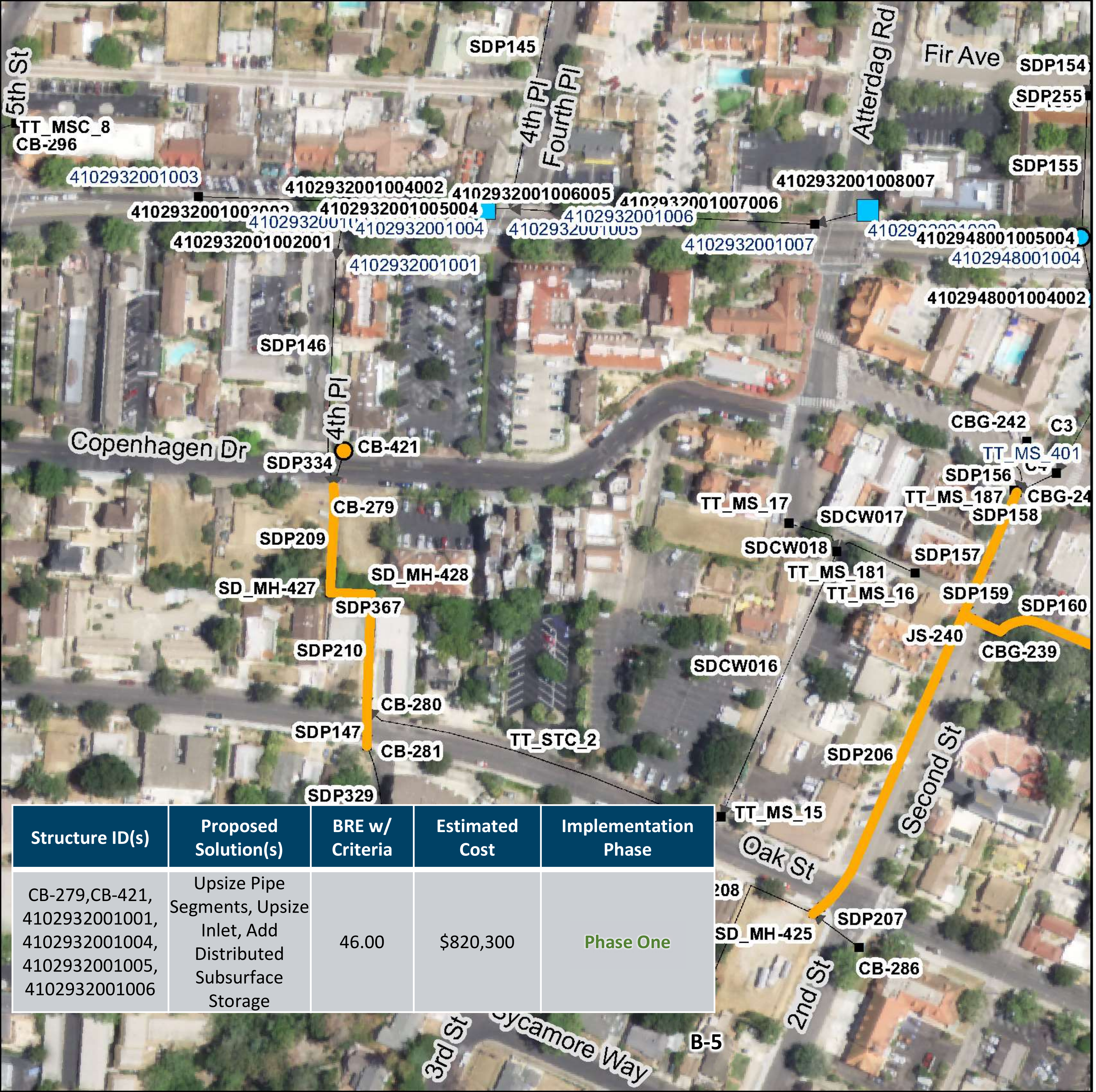
Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH
The City of SOLVANG Danish Capital of America

N
0 80 160 Feet

Solvang Master Plan
Mission Dr & 4th Place



Proposed Condition
100-year, 24-hour event

Proposed Improvements

- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure
Private Structure
Caltrans Structure

- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
CB-279,CB-421, 4102932001001, 4102932001004, 4102932001005, 4102932001006	Upsize Pipe Segments, Upsize Inlet, Add Distributed Subsurface Storage	46.00	$820,300	Phase One

TETRA TECH

The City of SOLVANG Danish Capital of America

N

0 100 200 Feet

Solvang Master Plan
Copenhagen Dr & 2nd St

Proposed Condition
100-year, 24-hour event

Proposed Improvements
- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH
The City of SOLVANG Danish Capital of America

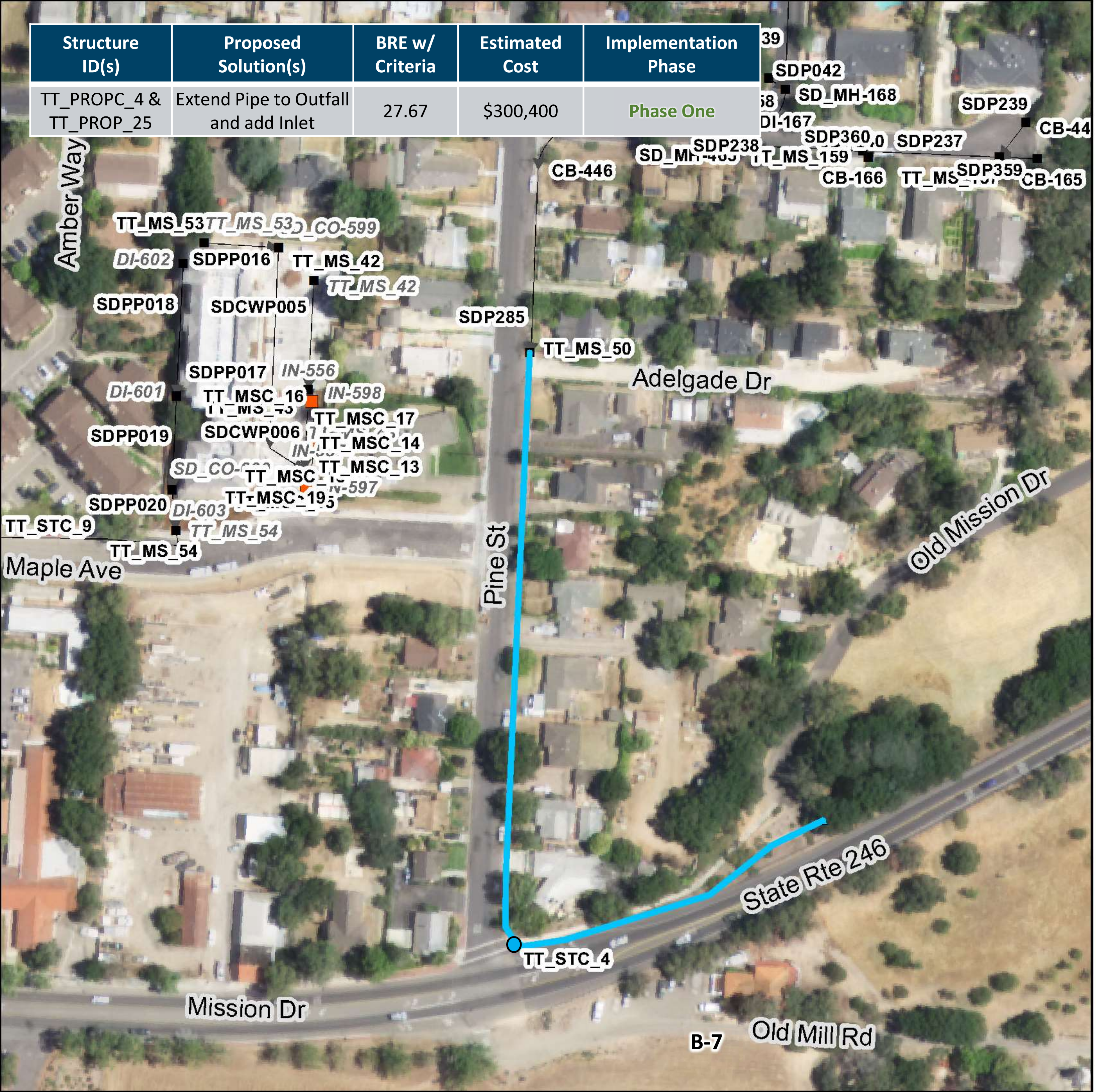
N

0 95 190 Feet

Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
4102948001004, 4102948001001, SDP160, SDP206, SDP157	Upsize Pipe Segments, Upsize Inlets	53.00	$996,100	Phase One

Solvang Master Plan
Maple Ave & Pine St

Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
TT_PROPC_4 & TT_PROP_25	Extend Pipe to Outfall and add Inlet	27.67	$300,400	Phase One



Proposed Condition
100-year, 24-hour event

Proposed Improvements

- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure

Private Structure

Caltrans Structure

- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

The City of SOLVANG Danish Capital of America

N

0 80 160 Feet

Solvang Master Plan
Viborg Rd

Proposed Condition
100-year, 24-hour event

Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
CB-146, SDP015, SDP016	Upsize Inlet and Upsize Pipes	15.33	$194,300	Phase Three

Proposed Improvements
- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

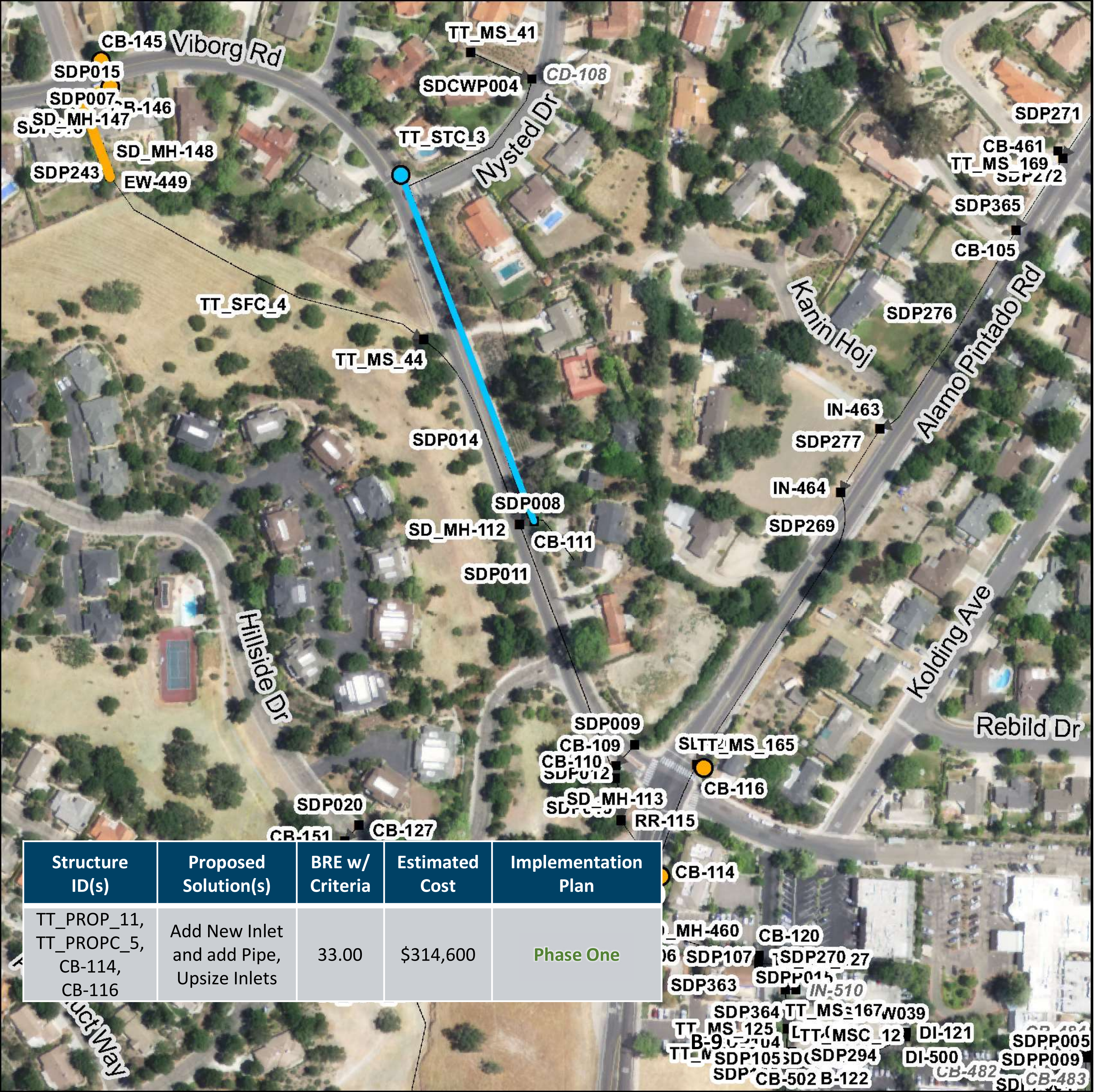
Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH
The City of SOLVANG Danish Capital of America

N
0 50 100 Feet

Solvang Master Plan
Viborg Rd & Alamo Pintado Rd



Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Plan
TT_PROP_11, TT_PROPC_5, CB-114, CB-116	Add New Inlet and add Pipe, Upsize Inlets	33.00	$314,600	Phase One

Proposed Condition
100-year, 24-hour event

Proposed Improvements
- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

The City of SOLVANG Danish Capital of America

N

0 130 260 Feet

Solvang Master Plan
Coyote Creek Rd

Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
TT_PROPC_7, TT_PROP_18, SDP352	Add New Inlet and Pipe, Upsize Pipe	17.00	$214,000	Phase Three

Proposed Condition
100-year, 24-hour event

Proposed Improvements
- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

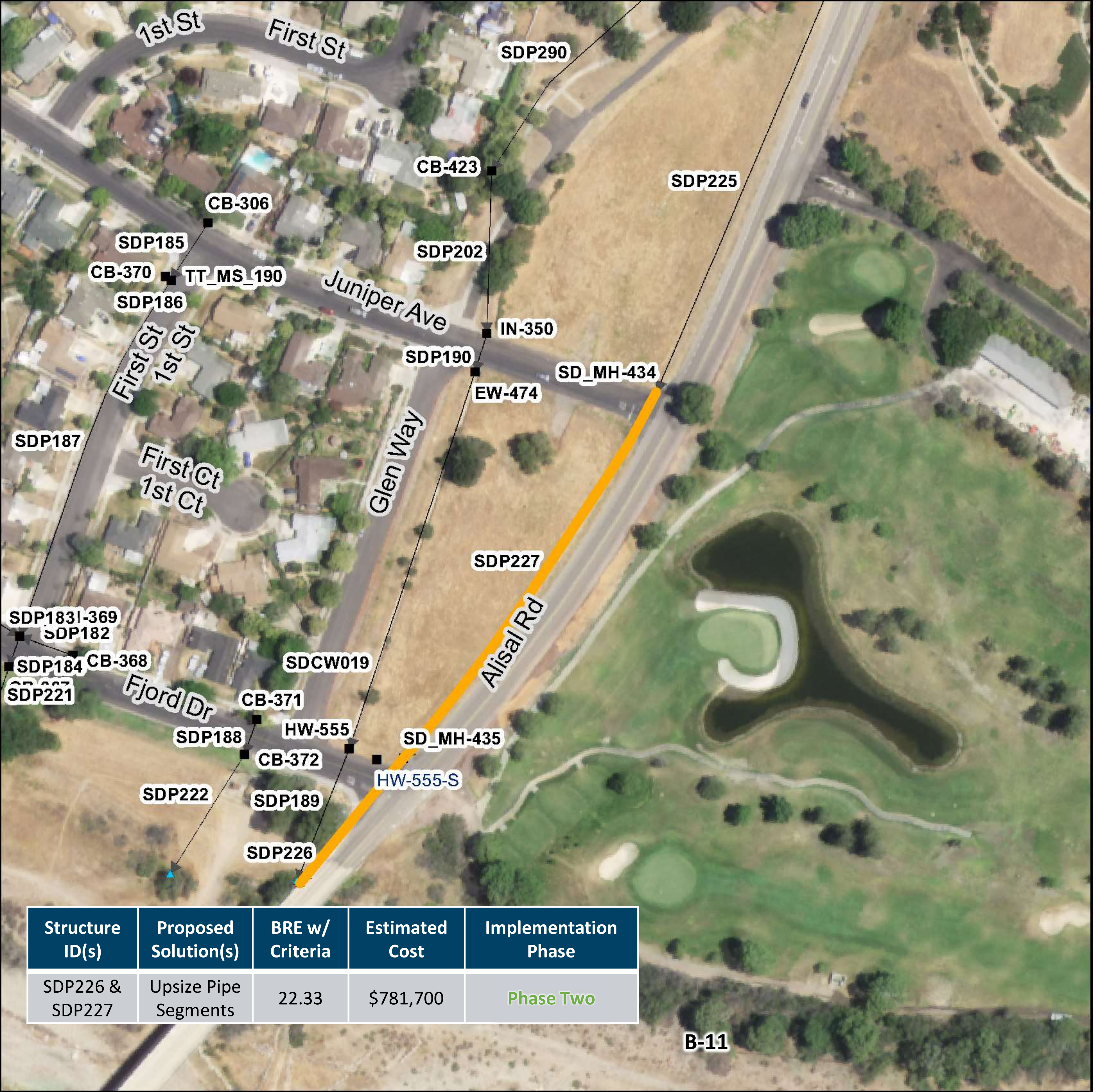
The City of SOLVANG Danish Capital of America

N

0 87.5 175 Feet

Solvang Master Plan
Alisal Rd & Juniper Ave

Proposed Condition
100-year, 24-hour event



Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
SDP226 & SDP227	Upsize Pipe Segments	22.33	$781,700	Phase Two

Proposed Improvements

- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure

Private Structure

Caltrans Structure

- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

TETRA TECH

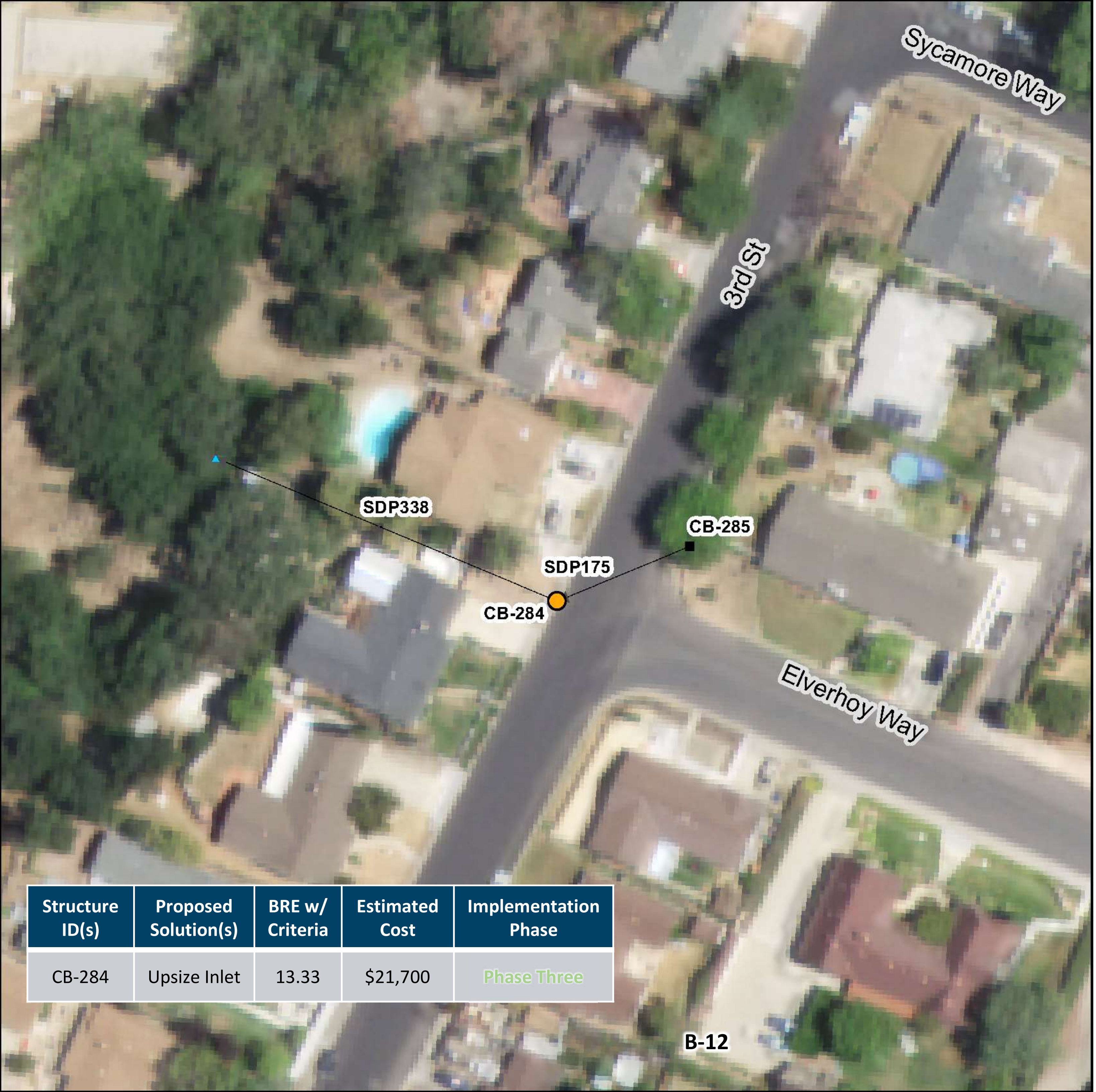
The City of SOLVANG Danish Capital of America

N

0 100 200 Feet

Solvang Master Plan
Elverhoy Way

Proposed Condition
100-year, 24-hour event



Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
CB-284	Upsize Inlet	13.33	$21,700	Phase Three

Proposed Improvements

- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure

Private Structure

Caltrans Structure

- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map

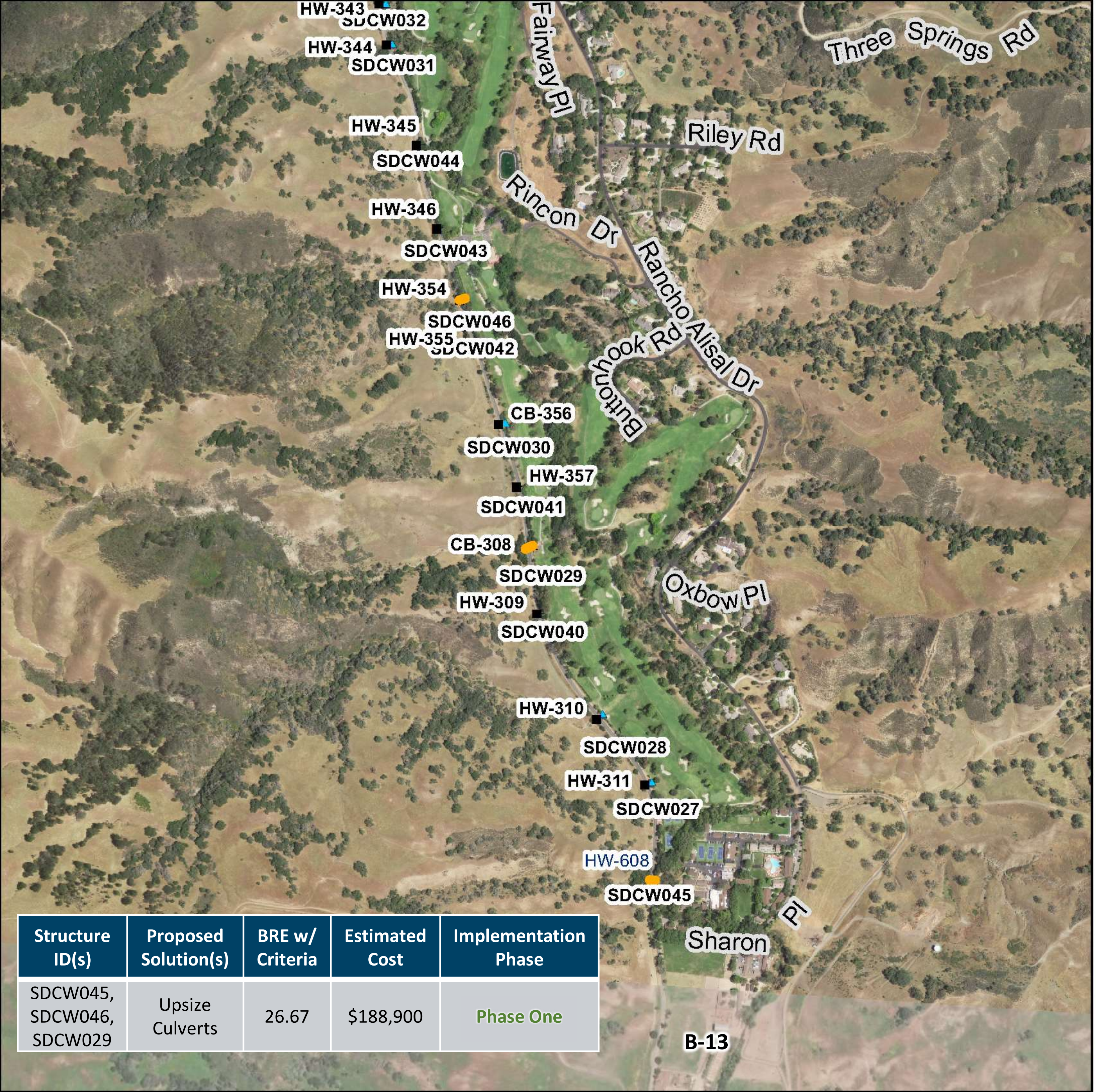
TETRA TECH

The City of SOLVANG Danish Capital of America

N

0 37.5 75 Feet

Solvang Master Plan
S Alisal Road



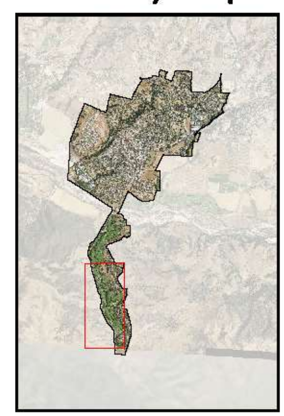
Structure ID(s)	Proposed Solution(s)	BRE w/ Criteria	Estimated Cost	Implementation Phase
SDCW045, SDCW046, SDCW029	Upsize Culverts	26.67	$188,900	Phase One

Proposed Condition
100-year, 24-hour event

Proposed Improvements
- New Inlet
- Upsized Inlet
- New Subsurface Storage
- New
- Upsized

Public Structure
Private Structure
Caltrans Structure
- Outfalls
- Conveyance
- Inlet Drainage Area

Vicinity Map



TETRA TECH
The City of SOLVANG Danish Capital of America

N
0 500 1,000 Feet

APPENDIX C: PROPOSED IMPROVEMENTS COST DETAIL

Table 1. Pipe Improvements Cost Detail

Asset ID	Location	Proposed Solution Type	Upsize/New	Length (ft)	Depth (ft)	Original Diam. (ft)	New Diam. (ft)	Construction Costs	Design & Planning Costs	Environmental Permitting	Construction Mgmt. Costs	Contingency	Mobilization	Total Cost
SDP226	Alisal & Juniper	Upsized Pipes	Upsize	194.7	10.0	3	3.5	$134,941	$13,494	$2,699	$10,121	$40,482	$6,747	$208,500
SDP227	Alisal & Juniper	Upsized Pipes	Upsize	535.2	10.0	3	3.5	$370,993	$37,099	$7,420	$27,824	$111,298	$18,550	$573,200
SDP058	Chalk Hill & Fredensborg Cyn	Upsized Pipes	Upsize	135.5	5.0	2	3	$80,771	$8,077	$1,615	$6,058	$24,231	$4,039	$124,800
SDP171	Chalk Hill & Fredensborg Cyn	Upsized Pipes	Upsize	46.8	10.0	2	3	$28,205	$2,821	$564	$2,115	$8,462	$1,410	$43,600
SDP157	Copenhagen & 2nd	Upsized Pipes	Upsize	159.8	4.6	2.5	3	$100,036	$10,004	$2,001	$7,503	$30,011	$5,002	$154,600
SDP159	Copenhagen & 2nd	Upsized Pipes	Upsize	48.3	4.6	2.5	3	$30,257	$3,026	$605	$2,269	$9,077	$1,513	$46,800
SDP160	Copenhagen & 2nd	Upsized Pipes	Upsize	354.8	5.1	2.5	3	$222,077	$22,208	$4,442	$16,656	$66,623	$11,104	$343,200
SDP206	Copenhagen & 2nd	Upsized Pipes	Upsize	402.8	5.0	2.5	3	$252,177	$25,218	$5,044	$18,913	$75,653	$12,609	$389,700
SDP352	Coyote Creek	Upsized Pipe	Upsize	56.3	7.0	3	3.5	$39,045	$3,904	$781	$2,928	$11,713	$1,952	$60,400
TT_PROPC_7	Coyote Creek	New Pipe	New	226.5	6.0	na	3	$87,430	$8,743	$1,749	$6,557	$26,229	$4,371	$135,100
TT_PROPC_4	Maple & Pine	New Pipe	New	936.6	3.8	na	1.5	$182,401	$18,240	$3,648	$13,680	$54,720	$9,120	$281,900
SDP147	Mission & 4th	Upsized Pipes	Upsize	44.5	7.4	2.5	3	$28,153	$2,815	$563	$2,112	$8,446	$1,408	$43,500
SDP209	Mission & 4th	Upsized Pipes	Upsize	126.7	8.8	2	2.5	$68,795	$6,879	$1,376	$5,160	$20,638	$3,440	$106,300
SDP210	Mission & 4th	Upsized Pipes	Upsize	136.6	6.6	2	2.5	$74,213	$7,421	$1,484	$5,566	$22,264	$3,711	$114,700
SDP367	Mission & 4th	Upsized Pipes	Upsize	49.5	10.3	2	2.5	$27,705	$2,770	$554	$2,078	$8,311	$1,385	$42,900
SDP015	Viborg	Upsized Pipes	Upsize	50.8	4.9	1.75	2.5	$27,231	$2,723	$545	$2,042	$8,169	$1,362	$42,100
SDP016	Viborg	Upsized Pipes	Upsize	97.7	9.0	1.75	2.5	$53,058	$5,306	$1,061	$3,979	$15,917	$2,653	$82,000
SDP243	Viborg	Upsized Pipes	Upsize	36.3	2.0	1.75	2.5	$19,423	$1,942	$388	$1,457	$5,827	$971	$30,100
TT_PROPC_5	Viborg & Alamo Pintado	New Pipe	New	594.2	3.2	na	1.5	$115,733	$11,573	$2,315	$8,680	$34,720	$5,787	$178,900

Table 2. Inlet Improvements Cost Detail

Asset ID	Location	Proposed Solution Type	Upsize/New	Depth (ft)	Orig. Length (ft)	New Length (ft)	Construction Costs	Design & Planning Costs	Environmental Permitting Costs	Construction Management Costs	Contingency	Mobilization	Total Cost	Potential to Upsize Further
CB-257	West Chalk Hill	Upsized Inlet	Upsize	3.1	3.5	15	$24,060	$7,218	$1,444	$5,774	$9,624	$1,203	$49,400	Yes
CB-146	Viborg	Upsized Inlets	Upsize	3.8	7.5	12	$19,560	$5,868	$1,174	$4,694	$7,824	$978	$40,100	Yes
CB-114	Viborg & Alamo Pintado Pintado	Upsized Inlets	Upsize	5.1	15.0	21	$33,060	$9,918	$1,984	$7,934	$13,224	$1,653	$67,800	Yes
CB-116	Viborg & Alamo Pintado	Upsized Inlets	Upsize	3.0	8.0	15	$24,060	$7,218	$1,444	$5,774	$9,624	$1,203	$49,400	Yes
CB-284	Elverhoy & 3rd	Upsized Inlet	Upsize	3.3	2.0	6	$10,560	$3,168	$634	$2,534	$4,224	$528	$21,700	Yes
CB-421	Mission & 4th	Upsized inlet	Upsize	3.9	4.0	21	$33,060	$9,918	$1,984	$7,934	$13,224	$1,653	$67,800	Yes, with pipe upsizing
TT_PROP_11	Viborg & Alamo Pintado	New Inlet	New	3.8	na	6	$9,000	$2,700	$540	$2,160	$3,600	$450	$18,500	Yes
TT_PROP_18	Coyote Creek	New Inlet	New	6.0	na	6	$9,000	$2,700	$540	$2,160	$3,600	$450	$18,500	Yes
4102948001001	Copenhagen & 2nd	Upsize Inlet	Upsize	3.0	4.0	9	$15,060	$4,518	$904	$3,614	$6,024	$753	$30,900	No
4102948001004	Copenhagen & 2nd	Upsize Inlet	Upsize	3.0	4.0	9	$15,060	$4,518	$904	$3,614	$6,024	$753	$30,900	No
TT_PROP_25	Maple & Pine	New Inlet	New	3.8	na	6	$9,000	$2,700	$540	$2,160	$3,600	$450	$18,500	Yes

SDPSDTable 3. Culvert Improvements Cost Detail

Asset ID	Location	Proposed Solution Type	Upsize /New	Length (ft)	Depth (ft)	Original Diam. (ft)	New Diam. (ft)	Construction Costs	Design & Planning Costs	Environmental Permitting Costs	Construction Management Costs	Contingency	Mobilization	Total Cost
SDCW045	S Alisal	Upsized Pipes	Upsize	36.0	5.2	1.5	2	$25,772	$7,732	$1,546	$6,185	$10,309	$1,289	$52,900
SDCW046	S Alisal	Upsized Pipes	Upsize	38.6	2.0	1.5	2	$26,516	$7,955	$1,591	$6,364	$10,606	$1,326	$54,400
SDCW029	S Alisal	Upsized Pipes	Upsize	50.6	3.5	2	2.5	$39,770	$11,931	$2,386	$9,545	$15,908	$1,989	$81,600
TT_MSC_28	Fredensborg Cyn Rd	Upsized Pipes	Upsize	77.9	9.4	4	8	$156,924	$15,692	$3,138	$11,769	$47,077	$7,846	$242,500
TT_MSC_25	Fredensborg Cyn Rd	Upsized Pipes	Upsize	36.2	8.0	4	8	$95,194	$9,519	$1,904	$7,140	$28,558	$4,760	$147,100

Table 4. Subsurface Storage Cost Detail

Asset ID	Location	Proposed Solution Type	Upsize/New	Flooded Volume (ft3)	Design Volume (ft3)	Depth (ft)	Project Area (ft2)	Width (ft)	Depth to Invert (ft)	Length (ft)	Construction Costs	Design & Planning Costs	Environmental Permitting Costs	Construction Management Costs	Contingency	Mobilization	Total Cost
4102932001005	Mission & 4th	Distributed Storage	New	3,476	6,952	9.5	805	6	4.9	122	$95,506	$9,551	$1,910	$716	$28,652	$4,775	$141,200
4102932001008	Mission & 4th	Distributed Storage	New	7,486	14,972	9.5	1,734	6	2.7	263	$205,685	$20,568	$4,114	$1,543	$61,705	$10,284	$303,900

Table 5. Detailed Unit Costs for Estimates

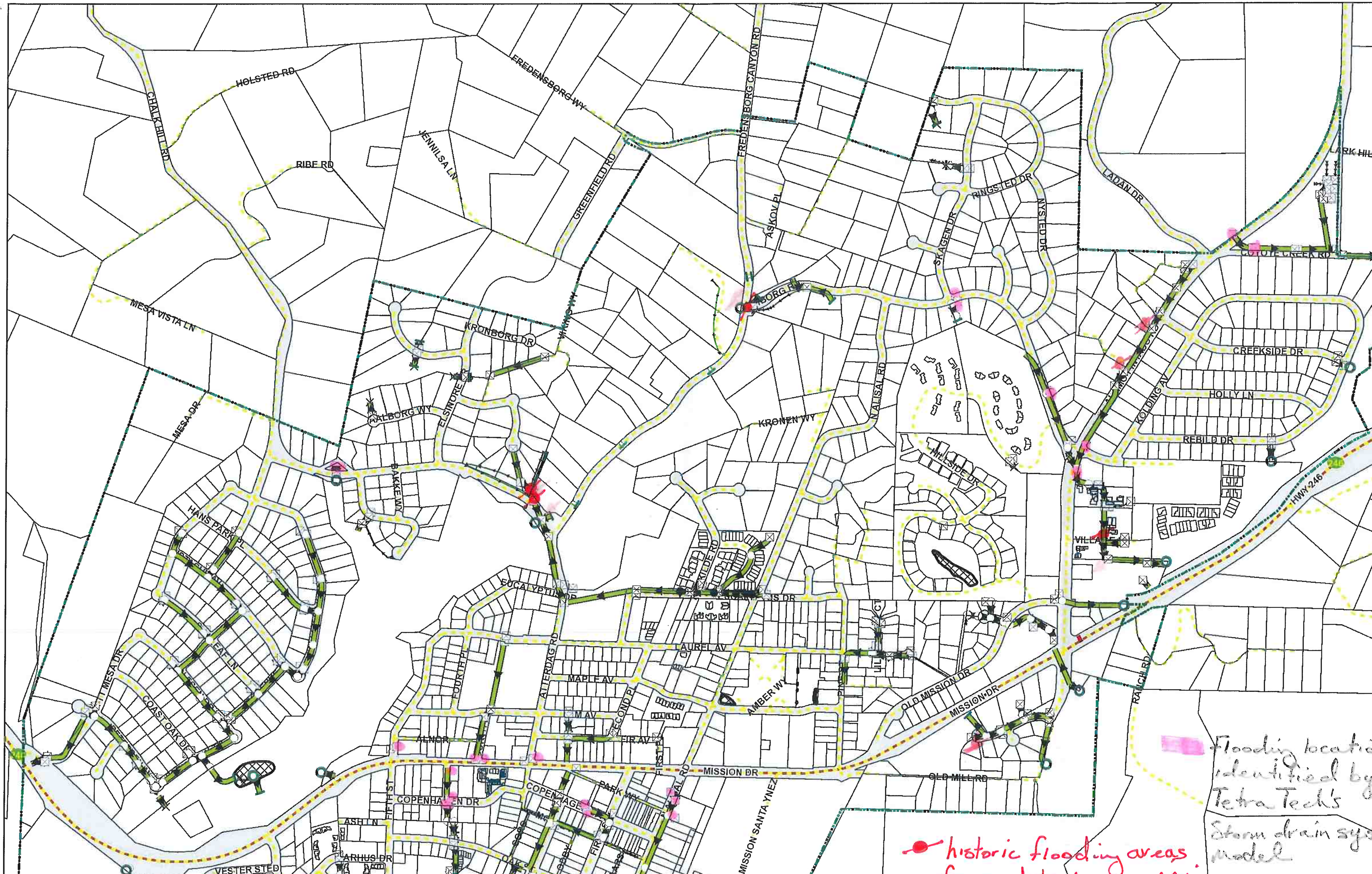
Grey Infrastructure Costs			
Pipe Improvements	**Pipe Removal**		
Diameter (in.)	**Material**	**Construction Cost per LF**	**Source**
up to 12"	RCP	$150	Solvang Recent Bids
15" to 18"	RCP	$180	
21" to 24"	RCP	$210	
27" to 36"	RCP	$240	
42" to 48"	RCP	$270	
60" to 84"	RCP	$300	
Pipe Improvements	**New Pipe Installation**		
Diameter (in.)	**Material**	**Construction Cost per LF**	**Source**
18	RCP	$180	Solvang Recent Bids
24	RCP	$240	
30	RCP	$300	
36	RCP	$360	
42	RCP	$420	
48	RCP	$480	
60	RCP	$600	
72	RCP	$720	
84	RCP	$840	
Pipe Improvements	**Trench Excavation**		
Depth (ft.)	**Material**	**Construction Cost per CY**	**Source**
1' to 4'	RCP	$10.40	RS Means 2018
4' to 6'	RCP	$8.20	
6' to 10'	RCP	$8.80	

10' to 14'	RCP	$9.90		
14' to 20'	RCP	$6.45		
Inlet Improvements	**Catch Basin Improvements**			
Length (ft.)	**Unit Cost (ea.)**	**Source**		
3	$4,500	Solvang Recent Bids		
6	$9,000			
9	$13,500			
12	$18,000			
15	$22,500			
18	$27,000			
21	$31,500			
Inlet Improvements	**Catch Basin Removal (Excavation & Backfill)**			
Length (ft.)	**Assumed Width (ft.)**	**Inlet Removal Cost**	**Source**	
All	4'	$1,560	Caltrans Cost Data	
Culvert Improvements	**Culvert Removal**			
Diameter (in.)	**Material**	**Construction Cost per LF**	**Source**	
up to 12"	RCP	$120	Solvang Recent Bids	
15" to 18"	RCP	$180		
21" to 24"	RCP	$240		
27" to 36"	RCP	$360		
42" to 48"	RCP	$480		
Culvert Improvements	**New Culvert Installation**			
Diameter (in.)	**Material**	**Construction Cost per LF**	**Headwall Cost per EA**	**Source**

18	RCP	$180	$4,000	Solvang Recent Bids		
24	RCP	$240	$5,000			
30	RCP	$300	$6,000			
36	RCP	$360	$8,000			
42	RCP	$420	$12,000			
72	RCP	$720	$16,000			
96	RCP	$960	$21,000			
Culvert Improvements	**Culvert Trench Excavation**					
Depth (ft.)	**Material**	**Construction Cost per CY**	**Source**			
1' - 4'	RCP	$13.00	Solvang Recent Bids			
4' to 6'	RCP	$10.25				
6' to 10'	RCP	$11.00				
10' to 14'	RCP	$12.38				
14' to 20'	RCP	$8.06				
Culvert Improvements	**Culvert Trench Backfill**					
Depth (ft.)	**Material**	**Construction Cost per CY**	**Source**			
1' - 4'	RCP	$8.26	RS Means 2018			
> 4'	RCP	$8.26				
Green Infrastructure Costs						
Subsurface Storage	**Installation**					
Width (ft.)	**Depth (ft.)**	**Excavation and Backfill per CY**	**Concrete Storage Cost per CY**	**Underdrain Cost per LF**	**Concrete Storage Cost per CY**	**Source**
6	9.5	$45	$270	$59.73	$271	Tetra Tech Subsurface Storage Projects in California
Other Project Costs						

Cost Type	Percentage of Construction Cost (< $50k)	Percentage of Construction Cost (> $50k)	Source
Design & Planning	30%	10%	Previous Tetra Tech Stormwater Projects in Santa Barbara
Environmental Permitting	6%	2%	
Construction Management	24%	7.5%	
Contingency	40%	30%	
Mobilization	5%	5%	

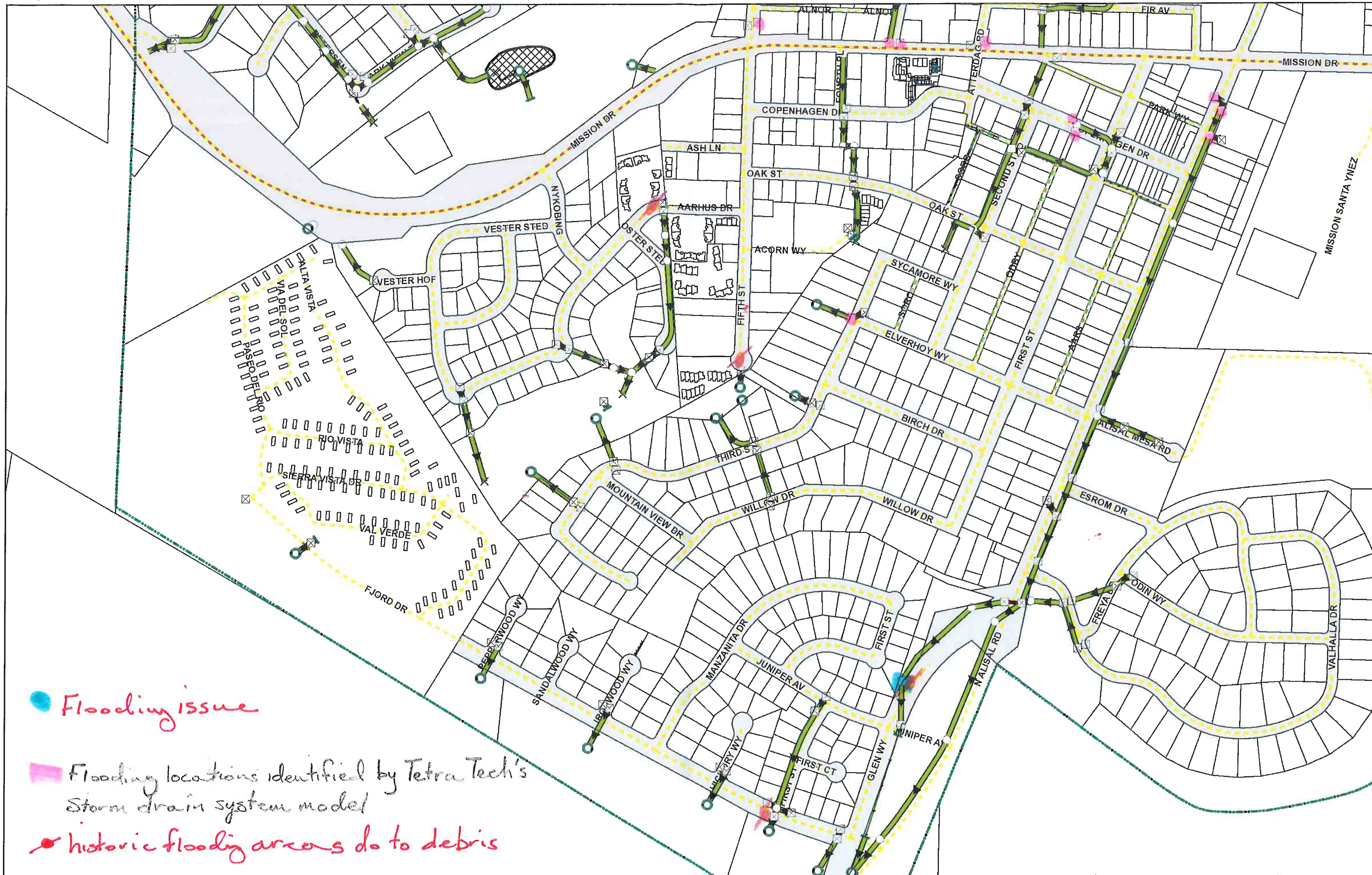
APPENDIX D: HISTORIC AND KNOWN FLOODING AREAS



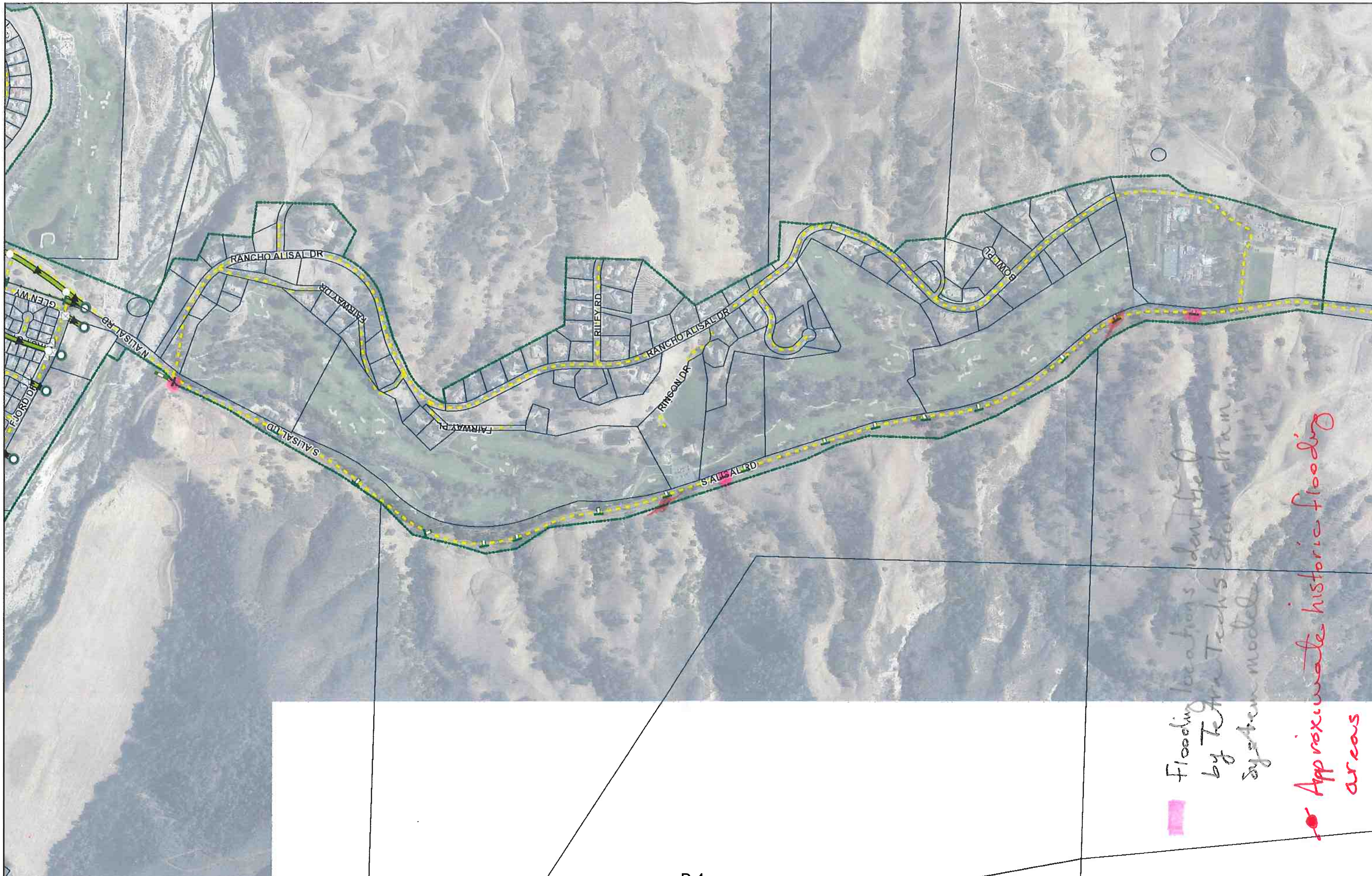
North of Mission

historic flooding areas from debris in addition to Tetra tech identified locations

South of Mission



South Alisal Road



APPENDIX E: RECENTLY COMPLETED/PLANNED DRAINAGE PROJECTS

Project Number	Project Name	Description of Stormwater Improvements
PW019	Oak St. Drainage Improvement Project	Enlarged catch basin on Oak Street and replaced 237 LF of existing 27" storm drain pipe with 36" storm drain pipe
PW050	FY 2014-15 Pavement and Drainage Improvement Project	Installed new catch basin on Alisal Road S/W of Valhalla Drive
PW056	Solvang Senior Apartments	Private development project that included 2,832 CF stormwater infiltration chamber
PW083	Merkantile Shopping Center Redevelopment	Private development project, which includes stormwater bioretention area and permeable pavers
PW089	Second Street Drainage Improvements (Phase 1)	Enlarge catch basin on Park Way (alley) and replace 353 LF of existing 24" storm drain with 36" storm drain pipe
PW109	Cottages on Old Mission	Private development project, which includes a landscape drain collection system, manhole and inlet installations, and permeable pavers for the parking lot
Planned	Second Street Drainage Improvements (Phase 2)	Upgrade outfall, install trash capture device, and replace 750 LF of existing 24" storm drain pipe with 36" storm drain pipe