EAST BOULDIN CREEK
AND
ANNIE STREET STORM SEWER SYSTEM IMPROVEMENTS

PRELIMINARY ENGINEERING REPORT

CIP PROJECT NUMBER: 5789.106

Prepared By:
City of Austin Public Works Department
Engineering Services Division
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April 29, 2021

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Prepared For:

City of Austin
Watershed Protection Department
Local Flood Hazard Mitigation Division

Prepared By:

City of Austin
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TABLE OF CONTENTS

Appendices

Appendix B – Flooding History

Appendix C – Existing Infrastructure Records

Appendix D – Environmental Review Records

Appendix E – Planned Projects

Appendix F – Rain Gardens and Detention Opportunities

Appendix G – Revised Pre-Project HEC-HMS Model

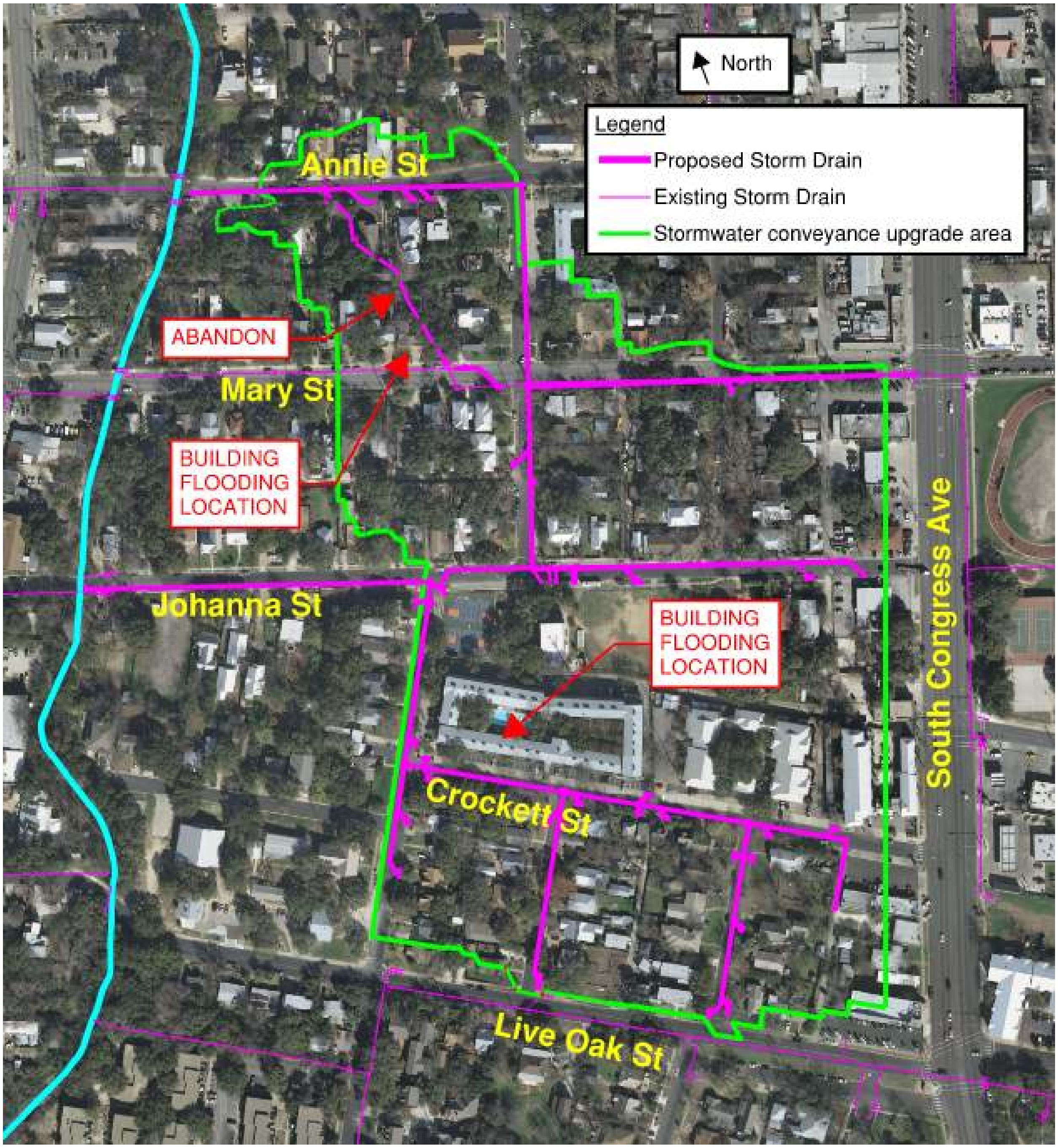
EXECUTIVE SUMMARY

The storm drain system for the neighborhood surrounding Annie Street between East Bouldin Creek and South Congress Avenue is undersized and does not fully convey peak storm water runoff per the City of Austin Drainage Criteria Manual. The system is undersized for 25-year and greater storm events. The system could be undersized for more frequent storm events, but that analysis is not included in the scope of this report. Watershed Protection Department has received complaints of building, yard and street flooding in the neighborhood served by this storm drain system. Building flooding occurs in two locations. A house at 304 W. Mary Street sits below grade and experiences flooding due to overflow from a curb inlet on Mary Street. Several condominium units at 300 Crockett Street flood due to runoff entering their property from Crockett Street. The condominium finished floor elevation is below the adjacent grade of Crockett Street and poor on-site drainage also contributes to flooding at the condominium complex.

The preliminary engineering report goals are to analyze the existing conditions and make infrastructure recommendations to mitigate localized flooding and meet current code requirements. Four different storm drain configurations, five different detention options and green infrastructure were considered during the investigation.

The recommended proposed infrastructure improvements are shown in the figure below and include constructing new storm drain systems on Crockett Street to Wilson Street then to Johanna Street that will outfall at East Bouldin Creek. A second new system includes new storm lines on Newton Street from Johanna Street to Annie Street that will discharge to East Bouldin Creek. The recommended improvements are expected to mitigate flooding due to stormwater runoff from the right-of-way, allow for abandonment of storm drain on private property, provide street conveyance that meets current code requirements and impact East Bouldin Creek flow peak rates for 2, 10, 25 and 100-year frequency storm events less than 1%. Approximately 6,380 linear feet of storm drain pipe are proposed and the total preliminary construction cost estimate is $5.73 million. The total estimated time for construction is 38 months, although improvements could be built in two separate phases. Proposed storm drain is shown in the figure below.

Proposed Storm Drain



1.0 INTRODUCTION

1.1 **Project Scope.** The purpose of this Preliminary Engineering Report is to investigate the requirements of the City of Austin Land Development Code (LDC), Environmental Criteria Manual (ECM) and Drainage Criteria Manual (DCM) for the East Bouldin Creek and Annie Street project area. This project's ultimate goals are to determine infrastructure improvements to mitigate local flooding and bring stormwater infrastructure to current code requirements in the neighborhood east of East Bouldin Creek and between Annie Street and Live Oak Street. The existing storm drain system for the project area is undersized and cannot convey the code required peak flows for the watershed. The system is antiquated, with some parts constructed as early as the 1930s, and does not meet current DCM standards. Additionally, part of the storm drain system runs across private property making repairs and maintenance difficult. Watershed Protection Department (WPD) has received reports of building, yard and street flooding in the area served by the storm drain system.

1.2 **Location.** The project area is located in south Austin, east of East Bouldin Creek, west of South Congress Avenue and from Annie Street to Live Oak Street. See location map in ***Appendix A***. Engineering Services Division (ESD) has reviewed in detail the storm drain system outfalling into East Bouldin Creek from the east at Annie Street. This system serves approximately 49 acres, which is comprised mainly of residential and multi-family lots with commercial property and a middle school situated along South Congress Avenue. The project area is undergoing some re-development of property in a manner that increases housing unit density.

Reports of building flooding come from two locations. A house at 304 W. Mary Street sits below street grade and floods when the curb inlet in front of the house overflows. Documented house flooding has happened at least three times since 2013. During the October 2013 “Halloween Flood”, the homeowner recorded a 13-inch watermark near the front door. The second building flooding location is at a condominium complex at 300 Crockett Street. Runoff from Crockett Street overtops the curb, flows into the complex and floods some of the ground level units. Ground level unit flooding has occurred at least nine times since 2004 according to the residents.

1.3 **Project Methodology.** Storm water runoff for the project area has been evaluated from two different perspectives. First, runoff patterns associated with East Bouldin Creek have been analyzed using HEC-HMS and HEC-RAS software. This method takes into account the watershed timing of flow to the creek. Second, the storm drain system has been evaluated with StormCAD software. This analysis evaluates proposed storm drains and ensures proposed pipes are sized and configured such that they are capable of conveying peak flows per the current Drainage Criteria Manual. Storm drain on Live Oak Street was evaluated using CivilStorm software and the dynamic wave solver in order to quantify storm drain overflow. Some overflow from the Live Oak Street system enters the project area.

2.0 PROJECT BACKGROUND

2.1 **Floodplain Maps.** Federal Emergency Management Agency (FEMA) 100-year and 500-year Flood Insurance Rate Maps (FIRM) and an additional map of the 25-year floodplain are included in ***Appendix A***. Although the floodplain remains narrow throughout the project area, some existing homes and structures are situated very close to East Bouldin Creek and are either fully or partially within the FEMA 100-year floodplain. FEMA maps are based on pre-Atlas 14 rainfall data.

2.2 **Flooding History.** A copy of flooding complaints was received from WPD on August 27, 2014 and is included in ***Appendix B***. A map of building, yard and street flooding locations evaluated in this report is also included in ***Appendix B***. A review of WPD's complaint database compiled through FY2020 and 311 calls placed through December 2020 reveals no new locations of building, yard or street flooding within the project area.

The first area of building flooding is in the vicinity of Annie and Mary Streets between Newton Street and East Bouldin Creek. In this area, the existing storm drain runs through private property and, as shown in the video inspection, continues to degrade. Section 5.2 of this report includes video inspection details. A 311 call from 304 W. Mary Street reported flooding inside the house on April 4, 2013. In April 1992 and 2008, a caller from 311 W. Annie Street reported yard flooding due to a broken storm drain pipe under the house. This caller also described flood water damage including a broken skirt around the house, washed away fence and significant yard erosion. The caller indicated that 307 W. Annie Street is also impacted by the same flooding.

The homeowner of 304 W. Mary Street describes flooding problems and interactions with City of Austin staff in a report submitted to the mayor on December 5, 2013. The report is included in ***Appendix B***. Since the storm drain pipe running from the inlet in front of 304 W. Mary Street diagonally across private property to Annie Street is undersized and damaged, storm water backs up at the inlet. This inlet is in a dip in the road and the house at 304 W. Mary Street is situated below the curb elevation. During large enough storm events, runoff flows over the curb and into and around the house at 304 W. Mary Street. The homeowner report provides evidence that water entered the house on April 2, 2013, May 10, 2013 and October 31, 2013. After the October 31, 2013 flood, photos from the homeowner show a 13-inch waterline near the front door. The homeowner further reports that exterior damage to the property included soil eroded from the foundation, fallen fences and soil eroded from the root system of a large oak tree. Interior damage required extensive repair; the homeowner replaced all downstairs wood floors, baseboards and sheetrock along the floor.

A second area that experiences building flooding is the Courtyard Condominium complex at 300 Crockett Street. WPD's complaint database includes reports of building flooding in July 2004, August 2004, January 2011, October 2012, and April 2013. An email from Kurt Ahlhorn, a member of the condominium Home Owner's Association board, documents additional building flooding in 2006, 2007, October 2013 and an event recent to February 2015 that involved removing 60 gallons of stormwater from a unit. This email is addressed to Joi Harden and dated February 8, 2015. See ***Appendix B***. Although on-site drainage for this complex is poor, significant runoff enters the property from Crockett Street. Video evidence shows that runoff on Crockett Street is not contained within the right-of way and instead flows onto the condo property. See ***Appendix B***. Since the finished floor of the condo building sits below grade of the adjacent roadway, roadway runoff flows through the front entrances, into the internal courtyard and floods units along the northeast corner of the complex.

ESD conducted a field visit to the Courtyard Condominiums during a rain event on June 15, 2015 to verify on-site drainage patterns and discuss flooding issues with Laurie Moses, a member of the Home Owner's Association board. Part of the complex's internal courtyard does not slope toward the exit point and ponding was observed near the units that flood. Ms. Moses described efforts taken by condominium residents during the 2015 Memorial Day storms. Their efforts successfully defended units from flooding and included manually moving water through the courtyard from the entrance toward the exit and stacking sand bags at doorways. Solutions to poor on-site drainage, including rain gardens and roof gutter revisions, have been discussed with the property owner since ponding could remain problematic even after the public storm drain infrastructure is upgraded.

A record from WPD's complaint databased dated May 23, 2002 documents a report of lot flooding at 1804 Newton Street. Follow up investigation by City of Austin staff in response to this complaint concluded the problem was caused by on-site drainage issues and is not the City of Austin's responsibility.

Other complaints logged for the project area include debris obstruction in East Bouldin Creek (420 W. Johana St.) and clogged curb inlets. The debris obstruction and clogged inlets can be attributed to maintenance issues and are not necessarily design or size related.

3.0 PUBLIC OUTREACH

3.1 **Public Meeting.** A public meeting was organized by WPD's Public Information Officer and held on June 2, 2015 at One Texas Center. The meeting was attended by Laurie Moses, a member of the Courtyard Condominiums Home Owner's Association board. No other neighborhood residents attended the meeting. Preliminary conceptual proposed improvements were presented by WPD and specific flooding issues at the Courtyard Condominiums were discussed. A follow up site visit at the condominium complex was scheduled and conducted on June 15, 2015.

3.2 **Site Visits and Correspondence.** On June 15, 2015, ESD representatives met Ms. Moses on site to discuss flooding at the Courtyard Condominiums (300 Crockett Street). The internal courtyard and area surrounding the complex were reviewed. Section 2.2 of this report includes greater detail from this meeting. ESD has also received a number of emails from project area residents documenting flooding as well as photos and videos of the flooding. This correspondence is included in ***Appendix B***.

4.0 QUALITY ASSURANCE AND QUALITY CONTROL

4.1 **Internal Quality Assurance and Quality Control Reviews.** Thu Cao, PE from ESD served as the internal QA/QC reviewer. She was not directly involved in the Annie Street Storm Sewer System Improvement project. She provided reviews of rain gardens, drainage area delineation, time of concentration calculations, inlet calculations, Pre-Project HEC-HMS and HEC-RAS models, Proposed Alternative 1 HEC-HMS and HEC-RAS models and existing and Proposed Alternative 1 StormCAD files. Ms. Cao has been the lead engineer for several storm drain improvement projects from preliminary engineering through construction. ***Appendix P*** includes internal QA/QC documentation.

4.2 **Watershed Protection Department Reviews.** WPD conducted three reviews at the completion of significant project milestones. The Pre-Project HEC-HMS model has been reviewed by Thuan Nguyen, PE from WPD's Watershed Engineering Division. Mr. Nguyen's review comments have been addressed and he accepted the model on June 9, 2015. The second review covered proposed storm drain upgrades and was completed by Jorge Morales, PE on September 28, 2015. Review comments have been incorporated into this report. Mr. Nguyen also reviewed the Proposed Alternative 1 HEC-HMS, Proposed Alternative 1 HEC-RAS and Proposed Channel Improvements HEC-RAS models. His comments were received on January 22, 2016 and have been addressed in this report. Jason Recker, PE reviewed the Alternative 4 HEC-HMS and StormCAD models in December 2020. ***Appendix P*** includes WPD review comments and responses.

5.0 EXISTING INFRASTRUCTURE

5.1 **Utility Records, Subdivision Plats and Easements.** Easement documentation has been found for part of the storm drain line running through private property between Mary and Annie Streets. This line crosses five separate lots, but deed records are only available for one lot, 1814 Newton Street. A second storm drain easement exists on the property at 211 W. Johanna Street. A sump inlet collects runoff from the alley behind Courtyard Condominiums (300 Crockett Street) and storm drain pipe running across 211 W. Johanna

Street conveys this runoff to the storm drain pipe on Johanna Street. Drainage easements also exist along East Bouldin Creek. A map of easement centerlines is shown in ***Appendix C*** along with documentation for the two storm drain easements. Linework shown in this map is from GIS Data Mart.

The project has been reviewed by the Austin Utility Location and Coordination Committee (AULCC) on August 7, 2014 and June 18, 2015. System maps have been received from a number of utilities with facilities in the area; utility company responses are summarized in ***Appendix C***. Project area base map has been created in Microstation V8 and AutoCAD 2020 that includes utility information for road, storm drain, water, wastewater, gas, electric and telecommunication systems as well as subdivision plats and easements. This map is provided digitally in ***Appendix Q***. Through the AULCC process, ESD has been directed to use the City's GIS Data Mart database as the primary information source for water, wastewater and storm drain lines. Record drawings have been used to update GIS line work when available. The existing storm drain system in the base map reflects information gathered during field visits.

5.2 **Storm Drain Video Inspection.** Video inspection of storm drain lines near the flooding between 304 Mary Street and 407 Annie Street was performed in 2008 and May 2013. Part of this storm drain runs through private property on Mary and Annie Streets. See ***Appendix C***.

The 2013 inspection reviewed three segments of storm drain pipe. The first inspection (13-7644-01) started at a manhole on Mary Street just west of Newton and continued through the storm drain in a northwest direction. This section exhibits numerous areas of broken or deformed pipe and several voids. The inspection did not continue past 221 feet due to an area of missing pipe that the video camera could not cross.

The second inspection (13-7644-02) started at a manhole on Annie Street between Newton Street and East Bouldin Creek. The inspection continued southwest through storm drain pipe that eventually connects to the first line inspected. This 169.5 foot section of pipe also exhibits areas of broken pipe and voids. There is an entire section of pipe that appears to have been patched/replaced with concrete walls and a steel plate; the bottom of the patch is missing and the video camera was unable to proceed. Notably, a manhole not documented in GIS was found at 407 W. Annie Street. Due to conditions that the camera could not traverse, approximately 50 feet of storm drain line was not inspected.

The third inspection (13-7644-03) evaluated the line on Annie Street that outfalls into East Bouldin Creek. This section exhibits fewer broken or patched areas, however, there is one broken joint about 10 feet before the outfall where soil is visible through the break. There is also an unknown utility line penetrating through the storm drain pipe.

The 2008 inspection covered the same section of pipe as the first 2013 segment (13-7644-01). Video taken at the broken pipe area past which the camera could not travel was compared for both years and shows deterioration. Between 2008 and 2013, the top of the pipe wall dropped and a section of the pipe bottom completely broke off and fell into a scour void. An entire section of pipe bottom is missing and soil and roots are visible in images from both years. See photos in ***Exhibit C.3***.

In spring 2015, WPD secured right-of-entry permission from the property owner and fixed the void and broken pipe shown in the first and second video inspections. Despite this repair, the entire line running through private property is antiquated and vulnerable to similar failures in the future. Releasing right-of-entry permission for repair operations is at the homeowner discretion since easement deed records are not available.

5.3 **Storm Drain Maintenance and Repair Records.** The Data Mart feature dataset, UTILITIESCOMMUNICATION.StormwaterInfrastructureField, has been reviewed for pertinent maintenance information. Several inlets in the project area are classified as Fair condition, although there is one inlet on Wilson Street listed in Poor condition due to clogging. The following charts summarize data from the Field Curb Inlet, Field Grate Inlet and Field Drainage Pipe GIS attribute tables. Fair is considered moderately deteriorated and Poor is significant deterioration.

Field Curb Inlet Attribute Table

Drainage ID Field	Location	Comments Field	Observation Field
101700	Mary St near Lively MS	None	Fair
101193	Mary St near Eva St	Photo recollected in 2009	Fair
100636	Eva St near Mary St	Photo recollected in 2010	Fair
100780	Alley south of Johanna Street, behind Boys and Girls Club	None	Fair
100927	Monroe St and Newton St	None	Fair
101623	Monroe St and Eva St	None	Fair
101286	Lindell Ave near Bartlett St	Cracked Concrete	Fair

Field Grate Inlet Attribute Table

Drainage ID Field	Location	Grate Open Percent Field	Observation Field
102391	Wilson St near Johanna St	30%	Poor

Field Combo Inlet Attribute Table

Drainage ID Field	Location	Comments Field	Observation Field
96763	Johanna St near creek	None	Fair
96694	South Congress near Live Oak	None	Fair
96743	Live Oak near Eva St	None	Fair

Field Drainage Pipe Attribute Table

Drainage ID Field	Location	Comments Field
436015	Johanna St near Newton St	Debris in pipe
436075	College Ave near Live Oak	Clogged with debris

5.4 **Storm Drain System GIS Revisions.** Several discrepancies have been discovered between GIS Data Mart shapefiles and field conditions during site visits. Revising the following items in the Data Mart database is recommended. Identification numbers listed below are from the Drainage ID field on the UTILITIESCOMMUNICATION.StormwaterInfrastructure dataset.

- Change status of Drainage Pipe 21868 and 21882 to inactive.
- Add the manhole at 407 W. Annie Street discovered during video inspection.
- Add a curb inlet on Eva Street, just south of Mary Street. This inlet connects to Drainage Pipe 21858 through a lateral that is also not shown in Data Mart.
- Delete Curb Inlet 21704 and Drainage Pipe 21707 on Mary Street just east of East Bouldin Creek; the inlet was not located in the field.
- Change status of Drainage Pipe 234859 to inactive. No field evidence was found of a line crossing the alley on Mary St between Newton and Eva.
- Delete Curb Inlets 21890 and 21891 in front of Lively Middle School. This inlet has not been located in the field.
- Move Curb Inlet 18958. This inlet is on South Congress Avenue, not Live Oak Street, and is adjacent to the bus stop at the South Austin Island.
- Add Linear Drain line to BMW shop at 2109 South Congress Avenue. Shown on site plan number SP-2012-0029C.
- Revise alignment of line on Johanna Street between Wilson Street and East Bouldin Creek.

6.0 ENVIRONMENTAL REVIEW

6.1 **Watershed Classification.** The entire project area is within the East Bouldin Creek watershed, which is classified as Urban under the 2013 Watershed Protection Ordinance. See ***Appendix D***.

6.2 **Erosion Hazard Zone and Erosion Inspection.** Proposed outfalls into East Bouldin Creek cross the Erosion Hazard Review Zone Buffer. This zone and associated development restrictions were established by the 2013 Watershed Protection Ordinance. Preliminary discussions with Janna Renfro, P.E. from WPD's Stream Restoration group indicate that protective works will be required at the outfall to prevent future erosion. At a minimum, protective works include appropriate energy dissipation and armoring of the channel bed and banks. Native limestone blocks or riprap and additional vegetation are preferred. Standard Details 508S-16 through 20 provide guidance to acceptable protective works. WPD's Stream Restoration Program will provide feedback on the outfall design and locations during future design phases. Additionally, Eric Loucks, P.E., Supervising Engineer for the Stream Restoration group, requests that the design team schedule a field visit with Ms. Renfro prior to beginning design. She will act as the Mission Integration and Prioritization Team representative. See ***Appendix D***.

In 2007 and 2008, WPD conducted an erosion assessment of East Bouldin Creek. Erosion Inspection forms have been completed during the assessment for a number of properties within the project area. Information from the 2007-2008 Erosion Site Inspection forms as well as any additional sites provided by Jana Renfro, P.E., are summarized below. A map and copies of the inspection forms are included in ***Appendix D***.

Summary of Erosion Inspection Sites Within the Project Area

Address	**Resource Threatened**	**Erosion Type Rating***
413 Mary	Fence	3
413 Mary	Yard	2
420 Johanna	Private wall and fence	wall = 4, fence = 3
419 Johanna	Private Wall	4
400 Live Oak	Tree	not available
500 Live Oak	Manhole/sewer line	2
1603 South 1st	Fence	3
1605 South 1st	Wall	4
1601 South 1st	Parking lot	2
1415 South 1st (listed as 1102 S. Congress Ave in GIS)	Tree and fence	3

*Type 1: Imminent threat to a habitable/primary structure or public roadway
Type 2: Threat to secondary structure/private property or public infrastructure
Type 3: Property or structure that may be threatened by future stream channel erosion
Type 4: Erosion that is deemed the property owner's responsibility.

6.3 **Endangered Species.** According to a map published by the Travis County Natural Resources Program, there are no endangered species within the project area. See ***Appendix D***.

6.4 **Vegetation.** A review of GIS Data Mart files has been conducted for the presence of the following features within the project area: wetlands, springs, grow zones, grasslands, rock outcrop and biologic resource buffers. A segment of wetlands is located in East Bouldin Creek upstream and downstream of the Johanna Street roadway culvert. The wetlands are described as fringe wetlands with flora including Fraxinus pennsylvanica, Taxodium distichum, Sabal minor, Ruellia brittoniana, Colocasia esculenta and other species. The Critical Environmental Buffer includes a note associated with Site Plan SP-2018-0017C that the 150-foot buffer was reduced to 50-feet with mitigation being three cisterns that drain to a flow spreader, woody invasive species removal and native grass planting.

6.5 **Water Quality.** Texas Commission on Environmental Quality's 2012 Texas Integrated Report lists "screening level concern" for a number of chemicals found in East Bouldin Creek sediment. Substances found include lead, phenanthrene and benz(a)antracene. The water quality report is included in ***Appendix D***. The City of Austin Critical Water Quality Zone (CWQZ) for Urban watersheds equals the 100 year fully developed floodplain in most locations. However, the CWQZ minimum and maximum widths are 50 and 400 feet from the creek centerline, respectively. See map in ***Appendix D***. There is no Transitional Water Quality Zone for Urban watersheds. Utility lines may cross the CWQZ if the applicant demonstrates that a feasible alternative does not exist, however, lines must follow the most direct path across the CWQZ. Green infrastructure, such as rain gardens, is not allowed within the CWQZ.

6.6 **Environmental Integrity Index.** A summary of WPD's Environmental Integrity Index report for East Bouldin Creek is included in ***Appendix D***. The overall watershed category is Fair while the water quality is described as average. Biological integrity is poor due in part to high impervious cover and the associated flashy stream flow events that scour the streambed.

6.7 **Geologically Sensitive Areas.** The project is not within the Barton Springs Zone, nor is it within the Edward's Aquifer buffer, recharge or contributing zones. Rock outcrops are not located within the project area.

6.8 **Historical Landmarks.** There are several historical landmark buildings within the project area. No conflicts exist since these buildings are located on private property and improvements are within the right-of-way. See ***Appendix D.***

6.9 **Features for Further Investigation.** GIS Data Mart shows three underground storage tanks along South 1st Street near the intersection with Annie, Mary and Johanna Streets. Storage tanks have the potential to leak and contaminants could migrate to the creek. Residue could be encountered during construction and removal of contaminated soils would be required. A Phase 1 Environmental Assessment should be conducted for the project area.

7.0 PLANNED PROJECTS AND AREA ACTIVITIES

7.1 **Planned Projects.** A search of the Infrastructure Management, Mapping, Planning and Coordination Tool (IMMPACT) database on January 6, 2021 found the following upcoming projects within the project area. See ***Appendix E***.

Project Name	Case Number	Activity Type	Description
PWD-1600 & 1811 Eva St.-UER	2020-189920 EX	Excavation Permit	Utility cut repair agreement between ATD and PWD.
AEU – Wilson Alley 2000 Blk Pole Install	2020-157937 EX	Excavation Permit	Installation of new pole in alley behind 2000 S Congress Ave.
AEU-PIKE – Newton St 2100 Alley – Pole Relocate	2020-188970 EX	Excavation Permit	Austin Energy is to replace an overhead span of secondary wire running in the alleyway between Eva St. and Newton St. A pole will be removed at 2102 Newton St. Alley and relocated to the property line of 2100/2102 Newton St. Alley in the alleyway.

AWU - 2110 EVA ST - Emergency Water Service Repair	2020-187269 EX	Excavation Permit	SR#885618 - CROSS ST LIVE OAK - EMERGENCY WATER SERVICE REPAIR

7.2 **Austin Utility Location and Coordination Committee.** The project has been reviewed by the Austin Utility Location and Coordination Committee (AULCC) on August 7, 2014 and June 18, 2015. Through this process, Public Works Department's Pavement and Infrastructure Division has been notified of storm drain improvements proposed in this report. Roadway maintenance in the project area will be adjusted to avoid streets with proposed storm drain projects. The Pavement and Infrastructure Division should be kept informed of any revisions to proposed storm drain locations during design phase. See email from Binaya Sharma in ***Appendix E***.

The Austin Water Operations Web Map was reviewed in December 2020 for proposed water and wastewater projects. There are three upcoming wastewater projects and one proposed water projects in the vicinity of the Annie Street storm drain improvements. There is a planned wastewater line at South Congress Avenue and Bartlett Street. The second proposed wastewater line is on Mary Street near the intersection with Eva Street. A proposed wastewater line at 211 West Johanna Street. There are two planned private water fire lines proposed on one private property at 211 West Johanna Street. It is believed that the proposed water and wastewater lines for project 2016-1123 are installed and active. The projects are listed in the table below. Austin Water reviewed the project area in December 2020 and is interested in partnering with WPD for installation of water and wastewater lines in the project area. A map of Austin Water proposed utility upgrades is included in ***Appendix E***.

Project Name	Plan Type	Project Year	Project ID	Notes
S. Congress & Live Oak WWL Relay & Spot Repair	Wastewater	2011	2007	Near proposed Bartlett Street and Live Oak
West Mary Street 6-inch WWL Ext	Wastewater	2012	0008	On Mary Street at Eva Street

SITE - LIVE OAK CONDOMINIUMS SP-2015-0460C	Water and wastewater	2016	1123	211 West Johanna Street. Two proposed 4-inch private fire lines.

7.3 **South Congress Area Activities.** Many events occur on and around South Congress Avenue throughout the year. Key events that could take place within or near the project area include: Austin Marathon, SXSW Festival, Statesman Capitol 10K Race, Urban Fest and the Austin Heart Walk.

8.0 GREEN INFRASTRUCTURE OPPORTUNITIES

8.1 **Potential Rain Garden Locations and Cost Effectiveness.** New rain gardens would be retrofit projects that would provide water quality controls for areas that currently have little to no water quality control measures. During field visits conducted in August and October 2014, ESD identified several potential rain garden locations. Tom Franke, WPD's rain garden specialist, has reviewed the sites and determined that the only feasible locations are at Live Oak/Bartlett and South Congress, Lively Middle School and right-of-way along South Congress near Lively Middle School. Two other sites, Milton Street at East Bouldin Creek and right-of-way surrounding the former Boys and Girls Club at 211 Johanna Street, are infeasible sites due to proximity to heritage trees, driveways and utilities. Note that Lively Middle School was named Fulmore Middle School when the rain garden analysis was completed.

Rain gardens at Live Oak/Bartlett had been previously planned by ESD but never constructed due to limited construction funding associated with the South Congress Streetscape Improvements project. It is feasible to update and permit the rain garden design with some minor revisions. The conceptual plan and preliminary cost estimate performed in 2011 are included in ***Appendix F.*** Methodology for updating cost estimates is provided in Section 18.9. Life cycle analysis is included in ***Appendix F***. Tom Franke notes that several items need to be included in order to maximize rain garden benefits:

- Remove inlet on South Congress south of Live Oak so the first flush can enter the rain garden.

- Add approximately four (4) inlets and valley gutters so runoff enters the rain garden first and bypass goes to inlets.

- Close part of the street at Live Oak and South Congress.

Lively Middle School is the second potential location for rain gardens. Several specific campus sites have been identified and studied for rain garden feasibility and cost effectiveness. Tom Franke has assisted ESD in identifying and reviewing these potential sites. ***Appendix F*** includes a memorandum detailing Total Suspended Solid (TSS) removal, groundwater infiltration and preliminary construction cost for all proposed rain garden locations at Lively Middle School. Methodology for updating cost estimates in the future is provided in Section 18.9 and life cycle analysis is included in ***Appendix F***. ***Appendix Q*** includes electronic copies of the Adams & Papa and Stormwater Load Analysis Tool (SLAT) model spreadsheets, which include cost benefit calculations.

Part of the middle school campus currently experiences erosion due to erosion caused by on-site storm water runoff. Rain gardens could mitigate this issue and would be beneficial to the school. Basketball and tennis courts situated along South Congress Avenue are currently being undermined by storm water runoff that is eroding base material from under the courts. This process also washes sediment onto the adjacent sidewalk and street. See photos in ***Appendix O*** at Location G.1. Although this area is dense with trees, leaving little space outside the critical root zone, rain gardens that are built up above ground using berms are a potential solution. The City arborist should be involved in the design process. See Proposed Rain Gardens B, C, D, E and F in ***Appendix F***. The TSS removal and estimated cost per pound of removal for these rain gardens is summarized in the table below. Cost effectiveness is calculated based on estimated construction costs. Soft costs design fees are not included in the estimate. Combining some of the proposed sites results in a lower cost per pound TSS removed.

Lively MS Proposed Rain Gardens – Erosion Control Benefit for AISD and TSS Removal Benefit for COA

		Adams & Papa Model		SLAT Model	
Proposed Rain Garden	**Construction Cost Estimate**	**Avg. Annual TSS Load Removed**	**Cost Effectiveness**	**Avg. Annual TSS Load Removed**	**Cost Effectiveness**
Combined B and C	$30,501	203 lb/yr	$13.39/lb TSS removed	269 lb/yr	$10.11/lb TSS removed
Combined E and F	$15,586	58 lb/yr	$36.41/lb TSS removed	34 lb/yr	$63.35/lb TSS removed

Another potential rain garden location at Lively Middle School is situated adjacent to a parking lot. This location does not provide the school with erosion control benefits, but does have a very high TSS removal rate since it is configured to capture the first flush of roadway and parking lot runoff. The roadway and parking lot currently do not have any water quality controls. See Proposed Rain Garden A in ***Appendix F***.

Lively MS Proposed Rain Garden – TSS Removal Benefit for COA

		Adams & Papa Model		SLAT Model	
Proposed Rain Garden	**Construction Cost Estimate**	**Avg. Annual TSS Load Removed**	**Cost Effectiveness**	**Avg. Annual TSS Load Removed**	**Cost Effectiveness**
A	$23,253	206 lb/yr	$11.82/lb TSS removed	649 lb/yr	$3.75 /lb TSS removed

The right-of-way between South Congress Avenue and Lively Middle School represents another rain garden opportunity. A long, narrow series of cascading rain gardens is feasible between the middle school property and proposed sidewalk. The existing sidewalk would be relocated adjacent to the curb, providing access to back-in parking along South Congress Avenue. See Proposed Rain Gardens G - L in ***Appendix F***.

Proposed Rain Gardens in Right-of-Way – TSS Removal Benefit for COA

		Adams & Papa Model		**SLAT Model**	
Proposed Rain Garden	**Construction Cost Estimate**	**Avg. Annual TSS Load Removed**	**Cost Effectiveness**	**Avg. Annual TSS Load Removed**	**Cost Effectiveness**
Combined G - L	$79,595	170 lb/yr	$27.49/lb TSS removed	448 lb/yr	$10.45/lb TSS removed

8.2 **Austin Independent School District Partnering.** Several joint COA/Austin Independent School District (AISD) rain garden projects have been completed in recent years. ESD has met with WPD staff involved with these projects in order to define elements needed for a successful joint project. The following points are noted by WPD's Kathy Rock and Kristen Pipkin as necessary for success:

- Costs have been kept down by using volunteer labor and donated materials.
- Design cost has been kept down by partnering with the University of Texas's Civil Engineering professional development class. Students designed rain gardens as part of a final project.
- Highly motivated teachers, parents or community members often solicited and coordinated volunteers and donations.
- Support from the school principal.
- A highly visible site that can include educational signage.
- A plan for long-term maintenance.

ESD met with Lively MS Principal, Renny Swan, in September 2014 and he expressed support for a rain garden project that included an educational component for his students. However, at that time, AISD or the school did not have funds to contribute to a project.

Note that Lively Middle School was named Fulmore Middle School when the rain garden analysis was completed.

8.3 **Rain Garden Design Considerations.** Percolation tests have been conducted at proposed rain garden locations as shown in ***Appendix F***. If proposed locations shift during design, it is strongly recommended conducting new percolation tests at the exact proposed rain garden location. Even slight adjustments in location can result in significantly different infiltration rates. The City arborist should be consulted when proposed ponds are located near existing trees.

ECM 1.6.7.5.H.3 should be consulted during design phase for suggestions that can reduce maintenance needs. The rain gardens should be planted with turf grass for easier maintenance. A wildflower mix could be added to the turf to enhance aesthetics. Maintenance access should be considered during design phase. South Congress Avenue has parking adjacent to proposed rain gardens in the South Congress right-of-way. Bartlett Road includes parking adjacent to proposed rain gardens. Maintenance access to rain gardens on Lively campus should be discussed with the school principal.

Additional coordination and confirmation of continued support from the middle school principal is recommended if WPD wants to pursue the opportunities on or near an AISD campus.

The creek flow impact of rain gardens has not been performed for the recommended storm drain alternative (Alternative 4). Rain gardens cause a delay in the hydrograph which is expected to result in a slight flow increase at the creek since peak flow from rain garden drainage areas reaches the creek before the peak creek flow arrives at the creek junction. Further analysis is needed to determine if the hydrograph delay associated with the rain gardens results in an adverse impact to the creek.

9.0 DETENTION OPPORTUNITIES

9.1 **Lively Middle School.** Several detention opportunities exist on Lively Middle School campus. The center of the running track currently serves as detention, but the capacity could be increased by lowering the center field. The existing track pond outlets to a biofiltration strip at the corner of South Congress Avenue and Mary Street. An additional detention pond could be constructed at this location. A third option is to provide underground detention by replacing 155 linear feet of existing 15" storm drain pipe with 48" pipe and installing a downstream restrictor plate to regulate peak flow rates. While these measures would reduce downstream peak flows and help mitigate flooding, per DCM Section 2.2.1, watersheds are analyzed without detention unless the detention facility is maintained by the City. The City would need to enter a maintenance agreement with AISD and obtain written approval from WPD's Director in order to include benefits from detention facilities on AISD property in the watershed analysis. ***Appendix F*** includes a map of proposed detention pond locations and further analysis. Note that Lively Middle School was named Fulmore Middle School when the analysis was completed.

The design recommendation, Alternative 4, does not include detention at Lively Middle School.

9.2 **Hodges Street.** Hodges Street is a section of undeveloped right-of-way close to East Bouldin Creek and is a potential detention pond location. Preliminary review of Hodges Street geometry indicates that an underground detention pond is feasible, however, calculations have not been performed to assess the benefits of a detention pond at this location. The area is outside the 100-year floodplain and is located at the downstream end of the proposed Crockett Street storm drain system. The Phoenix House owns property on both sides of Hodges Street and a fence has been constructed that encloses the right-of-way. There is an existing 6" PVC waterline in this section of Hodges Street. Preliminary discussion with the Public Work's Office of the City Engineer indicates that this area could be used for detention. It is recommended that the directors of Public Works and Watered Protection Departments sign a Memorandum of Agreement before proceeding with further investigation. Maps and communication with the Office of the City Engineer are included in ***Appendix F***. See also photos at Locations E.3 and E.4 in ***Appendix O***.

The design recommendation, Alternative 4, does not include detention at Hodges Street.

10.0 TOPOGRAPHIC DATA

10.1 **Existing and Proposed Topography.** A digital base map for the project area has been constructed from 2012 Lidar topographic data, 2013 planimetric data and survey files provided by WPD. The topographic and planimetric data has been downloaded from the City of Austin's GIS Data Mart database. Survey data provided by WPD has been merged into the Data Mart Lidar file such that the survey data supersedes Lidar data. This information, along with site visits, was used to model existing and proposed hydrology and hydraulics for the project. Existing utility lines are also included in the base map, as described in Section 5.1. The map is provided in ***Appendix A*** and digitally in ***Appendix Q***.

10.2 **Existing and Proposed Watershed Delineation.** A site visit with WPD staff (Megan Norris, P.E.) in August 2014 enabled ESD to gain a better understanding of the project's drainage and local area flooding issues. Additional field visits have been conducted throughout the project in order to verify record drawings, Data Mart GIS information and on-site drainage patterns. Drainage areas have been delineated using the base map described above and field verified or revised to the greatest extent possible based on observations made from the right-of-way.

11.0 HYDROLOGIC ANALYSIS OF PRE-PROJECT EAST BOULDIN CREEK WATERSHED

11.1 **Method of Analysis.** WPD has established a method for evaluating the impacts of proposed projects to existing creeks. The method used in this study is based on the Effective HEC-HMS model of East Bouldin Creek, which was completed by Halff & Associates in July 2005 and provides the flow data for current FEMA floodplain delineations. WPD's evaluation method requires two new HEC-HMS models. The first is a revision to the Effective HEC-HMS model. This Pre-Project model includes additional flow junctions at every road in the project area that either crosses or dead-ends at East Bouldin Creek within the project area. The additional junctions provide points of comparison to evaluate the impact of improvements. Although the Mary Street Relief Line was constructed in 2020, the Pre-Project HEC-HMS model does not include the line. This allows comparison between a scenario before any improvements and a proposed scenario, which is after all improvements are complete. Additionally, diversions have been added at locations where runoff splits and flows in two different directions. The second model represents proposed conditions and includes all improvements. Flow data from these two HEC-HMS models are used in HEC-RAS to establish pre-project and proposed water surface elevations. The Effective HEC-HMS model was created before recent updates to Atlas 14 rainfall data. Per discussion with Watershed Engineering Division, the effective model 500-year storm is used as an approximation of the Atlas 14 100-year scenario and the effective model 100-year storm is used as an approximation of the Atlas 14 25-year storm. Any rise in water surface elevation between the pre-project and proposed models could be mitigated with channel improvements. ***Appendix G*** includes correspondence with WPD regarding the Mary Street Relief Line and Atlas 14 rainfall.

Watershed runoff for each sub-basin has been modeled in HEC-HMS Version 4.0 using the Soil Conservation Services (SCS) Unit Hydrograph. The SCS Type 3 storm duration is used for calculating the rainfall hyetograph. Total 24-hour precipitation depths for 2, 10, 25 and 100-year rainfall events are the same as in the Effective HEC-HMS model. Rainfall losses are calculated using the SCS Curve Number (CN) method.

Several different routing methods are used in the Pre-Project HEC-HMS model. Modified Puls is used for East Bouldin Creek reach elements; this is the same method used in the Effective HEC-HMS model. Several HEC-HMS reach elements representing storm drain or gutter flow are used to model flow diversions included in the pre-project models. The Kinnematic Wave and Lag routing methods are used for reach elements that represent storm drain and gutter flow. The storm drain travel time (pipe flow time) is calculated in the StormCAD models and the following equation is used to calculate gutter flow travel time. The equation is from Hydrologic Analysis and Design by Richard McCuen, p. 143

$$\boldsymbol{V = k(S)^{0.5}}$$

Where,

V = velocity (feet per second)
S = slope in (ft/ft)
k = 46.3 as found in Table 3-14

The Effective HEC-HMS model is run with a 2-minute time interval, but due to the smaller basin size in the pre-project model, a 1-minute interval is necessary. HEC-HMS Warning message 47184 states that the simulation time interval should not be greater than 0.29 x lag time. If the time interval is 2-minutes, the minimum lag time needed to avoid this warning is 6.9 minutes. However, several basins have lag times as short as 3.0 minutes. If the time interval is 1-minute, the minimum lag time needed to avoid the warning is 3.45 minutes. As a result, the Pre-Project HEC-HMS model time interval is 1-minute and the minimum lag time is set at 3.5 minutes. For comparison, the effective model has been run with a 1-minute time interval. The summary in ***Appendix G*** shows that flow values for a 1-minute interval are higher.

11.2 **Field Observations.** Watershed delineation for the Effective HEC-HMS model appears to be based on topography and does not consider the storm drain configuration. Watershed boundaries for the ESD revised models have been modified and delineated based on topography and storm drain configuration for the project area. The storm drain runoff pattern is used when topography routes runoff differently than the storm drain system. HEC-HMS diversion elements are used to represent situations where runoff captured by the storm drain system outfalls to East Bouldin Creek at a location that is different from where the bypass flow enters the creek.

11.3 **Pre-Project East Bouldin Creek HEC-HMS Model.** The Effective HEC-HMS (Eff_COA) model available on the Floodpro website has been downloaded and revised to reflect field observations and runoff coefficient values calculated for the project area. Several critical points have been added along East Bouldin Creek where proposed storm drain lines may outfall into the creek. Critical points are located at streets that cross or dead-end at East Bouldin Creek between Crockett Street and Monroe Street. Drainage areas to each critical point have been delineated based on base map topography, storm drain configuration and field observations. Curve numbers and impervious cover percentages have been calculated as described below for all revised drainage areas (EBLDN-A through EBLDN-S). Drainage areas that are not altered retain the original curve number, impervious cover and lag time values from the Effective HEC-HMS model. See ***Appendix G*** for maps of original and revised watersheds, model input data and model results.

In order to incorporate critical points into the existing HEC-HMS model, several junctions have been added to reach REBLDN070. An additional junction has also been added to reach REBLDN090 at the intersection of South Congress Avenue and East Bouldin Creek.

Flow that bypasses the Annie Street storm drain system and continues north on South Congress Avenue is routed to this junction. Storage-discharge functions have been revised for both of these reaches (REBLDN070 and REBLDN090). The Effective HEC-RAS model has been used as the routing run.

Two diversions are included in the Pre-Project HEC-HMS model in order to account for flow that bypasses the Annie Street storm drain system. The first, Diversion-R, is placed on Wilson Street just south of Johanna Street. At this location, a newer grate inlet captures some runoff before it enters the Annie Street system and routes it to East Bouldin Creek through storm drain pipe on Johanna Street. The Inflow-Diversion table is based on the flow captured by the Johanna System curb inlets. Calculation details are included in ***Appendix G***. From Diversion-R, flow is routed through the Annie Street or Johanna Street storm drain systems. These systems are modeled in HEC-HMS as reaches with the Kinematic Wave routing method. Storm drain pipe segments with similar slopes and diameters have been grouped together for input into HEC-HMS in order to reduce model complexity. Storm drain record drawings are included in ***Appendix I.***

The second diversion, Diversion-S, is placed at the intersection of South Congress Avenue and Mary Street. At this point, some runoff enters the Annie Street storm drain system and overflow continues north on South Congress Avenue. An Inflow-Diversion table is also used to model Diversion-S. Inflow has been calculated as the 2, 10, 25, 100 and 500 year Rational Method peak flow for the drainage area (EBLDN-S) flowing to the Diversion-S location. Diversion is the sum of flow captured by all inlets upstream of Diversion-S and flow from EBLDN-T for the corresponding return periods. Runoff from EBLDN-T directly connects to the storm drain system through pipe on Lively Middle School campus. Area EBLDN-T is the same as DA-A25 in storm drain system analysis. The upstream inlets include five on-grade inlets and two sump inlets. Diversion flow into the five on-grade inlets has been determined by representing them as one equivalent long inlet. An equivalent length has been chosen that gives an inlet capture rate similar to the sum of capture for the five individual inlets for a given return period. Diversion flow into each sump inlet has been calculated for each return period and added to the flow captured by the equivalent long inlet. This results in the final diversion flow values used in the Diversion-S Inflow-Diversion table.

From Diversion-S, runoff that continues north on South Congress Avenue is modeled by a reach element using the Lag method. Lag time has been calculated as the travel time north on South Congress Avenue from Mary Street to East Bouldin Creek.

11.4 **Percent Impervious Cover – Existing Conditions.** Existing percent impervious cover has been calculated for each drainage area from the 2013 Remaining Pervious shapefile (ENVIRONMENT.remaining_pervious_2013) that is available on Data Mart. Electronic shapefiles are included in ***Appendix Q.***

11.5 **Percent Impervious Cover – Ultimate Development Conditions.** Since East Bouldin Creek is classified as an urban watershed under the Watershed Protection Ordinance, the allowable impervious cover is limited by zoning requirements. Accordingly, the ultimate development conditions have been determined by the Future Land Use Map (FLUM) and the maximum impervious cover allowed by zoning. The FLUM has been downloaded from GIS Data Mart database. The Land Use and Zoning Matrix (Planning and Development Review Department, July 2011) and the City of Austin Zoning Guide (June 2014) have been used to designate allowable impervious cover percentages for the land uses shown on the FLUM. Notably, since the entire project area is subject to neighborhood plans adopted before January 2009, SF-4A is acceptable for the Single Family land use category. SF-4A allows for up to 65% impervious cover, which is higher than other more typical single family zones. The City of Austin's effort to re-write land development code is ongoing. Maximum allowable impervious cover could be lowered as part of the re-write process. However, WPD does not recommended using lower percentages in the design process since the code re-write timeline is unknown. Zoning documents and correspondence regarding impervious cover are included in ***Appendix H.***

In cases where the existing percent impervious cover exceeds the ultimate development percent impervious cover, the existing value is used. This occurs at two locations. Part of the Lively Middle School campus (drainage area DA-T) and an apartment complex at 300 Crockett Street both have an existing percent impervious cover of 88% while the maximum allowed under future zoning is 80%. The existing percent impervious cover is also used for the right-of-way (land use category 800) and parks (land use category 700); the existing conditions for these areas is considered fully built-out. The final ultimate percent impervious cover for each watershed basin is a weighted average based on land use area.

11.6 **Curve Number.** Curve Numbers are calculated based on Hydrologic Soil Group and the percent impervious cover for each drainage area. Soil Survey Geographical maps (SSURGO) and soil type descriptions have been downloaded from the National Resources Conservation Service (NRCS). See ***Appendix H.*** Soil type descriptions list the Hydrologic Soil Group for soil types shown on the SSURGO map. Three of the four soil types are listed as Hydrologic Soil Group D. The fourth soil type, UtD, is composed of Urban Land (40%), Austin soils (30%) and Whitewright soils (25%) and minor components (5%). All of these sub-types are listed as Hydrologic Soil Group D except Austin soils, which is classified as Type C. TR-55 Appendix A has been consulted to resolve this discrepancy and determine the Hydrologic Soil Group for UtD soil type. According to TR-55 Appendix A, disturbed soil profiles are classified by soil textures. Soil type UtD is silty clay for the first 36 inches of depth; this is classified in Appendix A as Hydrologic Soil Group D. As a result, the entire project area is considered Hydrologic Soil Group D. According to TR-55 Table 2-2a, the Curve Number for Group D open space in good condition is 80. HEC-HMS uses the open space Curve Number and the percent impervious cover to calculate a weighted average Curve Number for each drainage area. It should be noted that the effective model soil map includes Hydrologic Soil Group C; correspondingly, the Curve Number input values are lower, ranging from 74 to 80.

11.7 **Time of Concentration.** Time of concentration is calculated according to TR-55 and DCM 2.4.2. Manning's roughness coefficients have been assigned based on DCM Table 2-4. The total time is a sum of the times for sheet, shallow concentrated and gutter/channel flows. See ***Appendix H***. The shallow concentrated flow length is divided into paved or unpaved based on the percent impervious cover for the drainage area:

$$Paved\ length = \%\ Impervious\ Cover \times Total\ Shallow\ Concentrated\ Length$$

11.8 **Lag Time.** Lag time has been calculated from the time of concentration based on DCM Eq. 2-9:

$$\boldsymbol{Lag\ time = 0.6\ \times Tc}$$

Although the minimum time of concentration (5 minutes) results in a lag time of 3 minutes, a minimum lag time of 3.5 minutes is used in order to avoid HEC-HMS Warning 41784, which states that the simulation time interval should be greater than 0.29 x lag time. Since the minimum time interval is 1 minute, a minimum lag time of 3.5 minutes is necessary to avoid this warning.

11.9 **Routing Steps.** Routing steps, or subreaches, for the Modified Puls routing method and a 1-minute time have been calculated using the same equation presented in the Effective HEC-HMS model's Technical Support Data Notebook (Halff Associates, July 2005):

$$Routing\ Steps = \frac{reach\ length}{velocity \times time\ interval}$$

11.10 **Storage-Discharge Functions.** Two reaches in the Effective HEC-HMS model have been subdivided into smaller reaches as a result of adding junctions at proposed outfalls. The impacted reaches are REBLDN070 and REBLDN090. Revised Storage-Discharge functions used in the Pre-Project HEC-HMS model have been calculated by using the Effective HEC-RAS model as the routing run. For the 400 cfs run, flow optimization at Junction A is turned off; see Section 13.4 of this report for discussion of this issue. Total storage from the smaller reaches does not equal storage for the corresponding effective model reaches; the difference is slight for REBLDN070 and more pronounced for REBLDN090. For REBLDN090 and 2000 cfs, the storage in the effective model is approximately twice the summed storage in the pre-project model reaches. The storage-discharge tables in ***Appendix G*** include graphs comparing the effective model tables to the pre-project tables. The routing run used to develop effective model storage-discharge functions has not been found and as a result, analysis of the discrepancy cause has not been performed.

11.11 **Pre-Project HEC-HMS Flow Results.** The Pre-Project HEC-HMS model was submitted to WPD for review and approved by Thuan Nguyen, P.E. on June 9, 2015. Flow results are summarized in ***Appendix G*** along with flow results from the effective model. The comparison shows that pre-project model flows are higher than effective model flows. A sensitivity analysis has not been performed to identify the source of this discrepancy. The flowing list summarizes conceptual reasons that could contribute to the difference.

- The effective model time interval is 2-minutes while the pre-project model is 1-minute. This is due to shorter lag times in the pre-project model.
- Sub-basins EBLDN070, EBLDN080 and EBLDN100 have been divided into a number of smaller sub-basins in the pre-project model. Revised time of concentrations are shorter.
- All Modified Puls routing subreaches are doubled in the pre-project model. This is necessary to maintain calculation stability. See HEC-HMS Technical Reference Manual excerpt in ***Appendix H***.
- Storage for reaches REBLDN070 and REBLDN090 is different than the total storage for corresponding reaches in the pre-project model. The effective model routing run is not available for comparison.
- The increased Curve Number in the pre-project model. The effective model soil map includes Groups C and D while the pre-project model has only Group D.
- The effective model considers sheet flow up to 300 feet, but pre-project model lengths are limited by recent DCM changes to 100 feet.
- The pre-project model routes project area runoff to East Bouldin Creek based on topography and storm drain configuration; the effective model only considers topography.

12.0 HYDROLOGIC ANALYSIS OF PRE-PROJECT STORM DRAIN SYSTEM WATERSHEDS

12.1 **Method of Analysis.** Storm water peak flow rates for existing and proposed inlets and streets capacity have been calculated based on the Rational Method as described in DCM 2.4.0. Total runoff to each inlet is the sum of peak flow for the inlet's drainage area and any carryover flow from upstream inlets.

12.2 **Field Observations.** Drainage areas to each inlet have been delineated based on LIDAR topographic data and field visits. A field visits to the Lively Middle School campus was conducted on September 26, 2014 to verify on site drainage patterns. A field visit was made to the condominium complex at 300 Crockett Street on June 15, 2015 to verify on site drainage patterns and discuss flooding issues with Laurie Moses, a member of the Home Owner's Association board. Other field visits were made throughout Fall 2014 and

Spring 2015 to confirm drainage areas and flow patterns. See drainage area maps in ***Appendix I***.

Additional field visits were conducted in September and October 2014 to verify record drawings and WPD GIS information. Notably, limited record information was found for three short drain lines shown in WPD GIS; and, inlets to these lines were not located in the field. As a result, these lined have been considered abandoned and are not included in the analysis. Further investigation, such as video inspection of abandoned lines, is outside the scope of this report. See ***Appendix I.***

Field observations of the Lively Middle School campus helped delineate the area draining directly to the Annie Street storm drain system (DA-A25). Several school buildings drain to a pipe that connects directly to storm drain on South Congress Avenue, while runoff from the rest of campus flows overland to curb inlets.

12.3 **Rational Method C Coefficient.** The existing and ultimate development conditions C coefficient has been calculated for each inlet drainage area based on the percent of asphalt, concrete and grass cover. Weighted average C values based on these areas and C values from DCM Table 2-3 are presented in ***Appendix I***. The grass areas are considered fair condition and the slope ranges from flat to steep.

For existing land use conditions, the ENVIRONMENT.remaining_pervious_2013 shapefile from Data Mart is used to calculate percent impervious cover. The area of impervious cover that is asphalt is calculated from a composite shapefile titled EBC_asphalt area_20150227. This composite file is the result of intersecting two Data Mart shapefiles: TRANSPORTATION.transportation_features_2006.shp and TRANSPORTATION.paved_areas_2013. The files contain shapes of asphalt paved roads and other asphalt paved areas (such as parking lots), respectively. Any increase in impervious cover between the existing and ultimate development conditions is considered to be concrete. Electronic shapefiles are included in ***Appendix Q.***

For the ultimate development C coefficient, percent impervious cover is based on the Future Land Use Map. The calculation method for ultimate development percent impervious cover is described in Section 11.5.

12.4 **Time of Concentration.** Times of concentration are calculated as described in Section 11.7 of this report.

12.5 **Rational Method Intensity**. The existing storm drain system was evaluated before recent Atlas 14 rainfall data updates. Rainfall intensity for existing storm drain analysis was determined using pre-Altas 14 IDF curve coefficients and DCM Eq. 2-1:

$$i = a / (t+b)^c$$

where, a, b, c are found in Table 2-5 of an archived DCM version.

13.0 HYDRAULIC ANALYSIS OF PRE-PROJECT EAST BOULDIN CREEK

13.1 **Method of Analysis.** A one-dimensional steady flow analysis of water surface elevations in East Bouldin Creek has been performed using HEC-RAS Version 4.1.0. Input flow data is from the approved Pre-Project HEC-HMS model.

13.2 **Field Observations.** WPD channel improvement project photos have been reviewed for the time period after publication of the Effective HEC-RAS model (Halff Associates, July 2005). A discrepancy exists between pictures of the Cumberland bridge and the corresponding HEC-RAS cross-section. ***Appendix J*** includes pictures from WPD and HEC-RAS cross-section station 14298.

13.3 **Manning's n.** ESD's review of WPD channel improvement projects also included an assessment of the Manning's n coefficient assigned to cross-sections along the creek. Several Manning's n coefficients have been changed in the Pre-Project HEC-RAS model to more accurately reflect improvements. ***Appendix J*** includes pictures and justification for revised n values.

13.4 **Pre-Project East Bouldin Creek HEC-RAS Model.** Water surface elevations for existing and ultimate development land use conditions have been computed for the pre-project scenario. The Effective FEMA HEC-RAS model has been modified based on flow data from the approved Pre-Project HEC-HMS model. For the project area, flow change locations have been added at all street crossings and flow data is from the approved Pre-Project HEC-HMS model. Downstream of the project area, flow change locations remain the same as the effective model. ***Appendix J*** includes a summary of flow change locations and HEC-HMS source data as well as pre-project water surface elevations.

Data for the 2-year storm is not part of the effective FEMA model. Data for this profile has been generated by running the Effective HEC-HMS model with a 2-year storm event. For all profiles, the Effective HEC-HMS model flow data is used upstream of the project area and flow data from the approved Pre-Project HEC-HMS model is used from the project area downstream to the confluence with the Colorado River. Another modification of the Effective FEMA HEC-RAS model has been made for the 2-year storm event at the Culvert Split. As noted on page 6 of the Halff and Associates Technical Support Data Notebook Section II – Hydraulics (July 2005), the split occurs at the culvert under South 1st Street at Oltorf Street; the Culvert Split conveys flow through the culvert and Reach 2 conveys flow over the roadway. During a 2-year storm event, flow is low enough that water remains in the culvert and the roadway is not overtopped. Since there is no split flow for very low flow storm events, flow optimization is turned off at Junction A for the 2-year profile.

The effective FEMA HEC-RAS model, which was developed using HEC-RAS Version 3.1.2, fails to produce results for the 25-year profile when run in HEC-RAS Version 4.1.0 without any modifications. The error message states, “flow optimization failed to converge” at Junction A even with 60 iterations. When the “maximum difference in junction split flow” (Calculation Tolerances) is changed to 0.08 feet from 0.02 feet, the split flow calculations do converge. As a result, the pre-project water surface elevations are calculated with a maximum 0.08 feet difference in junction split flow for the 25-year profile.

13.5 **Pre-Project East Bouldin Creek HEC-RAS Results.** Pre-Project HEC-RAS water surface elevations are provided in ***Appendix J*** along with effective model results. Pre-project water surface elevations are higher than effective model elevations at a number of cross-sections. The maximum difference inside the project area is 0.96 feet and occurs between Live Oak and Johanna Streets (Cross-section 11001) for the 100-year existing conditions profile. Cross-sections downstream of the project area also exhibit higher water surface elevations, notably between South Congress Avenue and Riverside Drive. The cause of the difference was not analyzed, but conceptual reasons are similar to those listed in Section 11.11 of this report.

13.6 **Flood Early Warning System Data.** WPD's Flood Early Warning System data for the one depth gauge located in the project area is included in ***Appendix J***. The gauge is a former USGS station (08157600) that was taken over by WPD as site Cooperative program at East Bouldin (CEB). CEB was discontinued in 2011 due to sediment build up and problems with the flow rating table. The nearest HEC-RAS cross section is 7780, near South 1st Street. Total 24-hour rainfall depths have been acquired from WPD for dates with the highest annual flow depth registered by CEB. Approximate storm event return periods have been assigned to these dates based on the pre-Atlas 24-hour rainfall depths found in Table 2-3 of an archived DCM version. The observed flow depth has been compared to model results for the effective and pre-project models. In all cases, the modeled depth exceeds the observed depth.

14.0 HYDRAULIC ANALYSIS OF PRE-PROJECT STORM DRAIN SYSTEMS

14.1 **Method of Analysis.** The existing storm drain system has been evaluated according to the methods described in HEC-22 as required by the current DCM. StormCAD Series 4 has been used to analyze pipe flows, velocities and Hydraulic Grade lines for the existing storm sewer system. Total runoff to each inlet is entered in StormCAD as Flow (Additional Subsurface) in the System Flows table. Total runoff equals the sum of Rational Method peak flow for the inlet's drainage area and carry over from upstream inlets. The Rational Method is a conservative analysis since it adds peak flow to peak flow at every curb inlet along the storm drain pipe. In contrast, HEC-HMS includes flow timing. StormCAD flow results for storm drain system outfalls are expected to be higher than HEC-HMS basin peak flows at corresponding locations due to the conservative (peak-on-peak) method of analysis used in StormCAD.

14.2 **Field Observations.** The StormCAD model reflects abandoned lines and GIS Data Mart revisions discussed in Sections 12.2 and 5.4, respectively.

14.3 **Pipe Data.** Record drawings are the primary source for pipe data for the existing system. ***Appendix I*** includes copies of the record drawings as well as a summary of pipe input data (diameter, length and slope) with the data source noted. Plan sheets for the Mary Street Emergency Relief Line are also included in the appendix.

14.4 **Inlet and Street Data.** WPD's DIG Data is the primary source of inlet geometry data. This information is available from the City's GIS Data Mart database under the data set titled UTILITIESCOMMUNICATION.StormwaterInfrastructureField. ESD field measurements supplement this information for cases where DIG Data is not available, or where DIG Data measurements appeared inaccurate during field visits. ESD field measurements are the source of street cross-slope and crown height while LIDAR is the source for street widths and longitudinal slope. Approximate curb split heights have been calculated based on LIDAR topographic data. Ground height at the right-of-way is assumed to be one inch above top of curb for street flow and code compliance analysis. This represents a typical standard cross-section with 1% cross-slope and ten feet between back of curb and right-of-way line. LIDAR data is too coarse to determine the right-of-way elevation with adequate precision for the project area and purchasing a survey exceeds the scope of preliminary engineering. For areas where the ground slopes down behind the curb or sidewalk (DA-A05 and DA-A21), runoff is considered outside the right-of-way if flow depth exceeds the curb height. Existing street geometry is used for proposed inlet calculations.

14.5 **Inlet Calculations.** Inlet calculations have been performed for ultimate development land use conditions for all existing inlets in the Annie Street Storm drain system and any inlets whose bypass contributes to this system. As stipulated in DCM Section 4.3.0, inlet calculations are based on the HEC-22 publication. Inlet calculation spreadsheets for the existing storm drain system are included in ***Appendix I***.

14.6 **Inlet Calculation "a" Value.** The "a" dimension required for HEC-22 calculations is shown in HEC-22 Figure 4-13 (p. 4-47). This is different from the "a" value shown in DCM Appendix D Figure 4-1. This discrepancy presents a problem for evaluation of the existing system since the “a” value collected by DIG data consultants more closely represents the DCM Figure 4-1 “a”. Although the DIG data methodology includes a graphic similar to HEC-22, the description for collecting the data more closely approximates the value of “a” shown in DCM Figure 4-1. To correct for this discrepancy, an equation has been developed to convert from aDIG to aHEC. A similar equation has been developed for proposed inlets based on typical curb inlet geometry and street cross-slope. This methodology was accepted by WPD during the Task 4 review process. See ***Appendix I***.

14.7 **Grate Inlet Splash-over Velocity.** Approximate splash-over velocity has been determined using HEC-22 Chart 5B and Equation 7-20 from the Urban Drainage and Flood Control District’s (UDFCD) Criteria Manual. Equation 7-20 calculates values for curves shown on Chart 5B. The UDFCD is based in Denver, Colorado. Chart 5B covers grate inlets up to 4.5-feet long. Equation 7-20 allows calculation of splash-over velocity for longer inlets, such as those found in the project area. See ***Appendix I***. None of the grate configurations in HEC-22 exactly match grates found in the field, so splash-over velocities for the most similar grates have been used.

14.8 **Street Ponded Width.** The maximum street ponded width is set at the distance from curb to crown. The flow depth in the gutter often exceeds the crown height for the existing storm drain system. However, the parabolic crown equation cannot be solved for ponded width if flow depth exceeds crown height.

14.9 **Tailwater Conditions.** Water surface elevations from the Effective FEMA HEC-RAS model have been used to establish tailwater conditions for storm drain modeling. Watershed Engineering previous allowed the use of coincident frequencies, as described in HEC-22 Section 7.1.5. Coincident peaks were used in the pre-project and Alternative 1 StormCAD models. The method used for Alternative 4 StormCAD model is described in Section 17.1. Coincident peak analysis can result in the return period for the tailwater water surface elevation being lower than the StormCAD model return period. The deciding factor is the ratio of upstream creek watershed area to storm drain system area. The ratio of upstream area to storm drain system area is approximately 17:1 for the Annie Street Storm drain system. As listed in HEC-22 Table 7-3, the 50-year water surface elevation can be used for the tailwater condition in the 100-year StormCAD model when the area ratio exceeds 10:1. WPD has provided an additional table from The City of Grand Prairie

Drainage Design Manual (Table 8.6) that includes the 25-year flood. The 10-year water surface elevation can be used for the 25-year StormCAD model when the area ratio exceeds 3:1. Appropriateness of this method has been verified by reviewing the timing to each outfall junction in the Pre-Project HEC-HMS model. Peak flows from the contributing storm drain system basin areas occur before the corresponding creek junction peak flows for all cases. Supporting documentation is included in ***Appendix I***.

14.10 **Existing Storm Drain System Evaluation.** A summary of code compliance issues for the existing storm drain configuration, pre-Atlas 14 rainfall and existing land use conditions is included in ***Appendix I***. Greater non-compliance with DCM criteria would be expected for Atlas 14 rainfall. Compliance with the DCM criteria requiring water to remain below top of curb for 25-year storms has been evaluated at each inlet. This criteria is not met for approximately half the inlets in the project area. The criteria requiring water to remain within the right-of-way for 100-year storms has also been evaluated at each inlet. Again, for approximately half the locations, this criteria is not met. See Section 14.4 of this report for a discussion of right-of-way elevation assumptions. Clear width analysis for roads with a "total clear width" requirement is only possible for streets with inlets on opposing sides of the street at a given point. Several streets do not meet clear width requirements. Additionally, the pipe system is undersized. The HGL exceeds 300 feet above ground elevation along South Congress Avenue and is at least 110 feet above ground elevation near 304 W. Mary Street for the 25-year storm. The DCM requires that the HGL is at least 6-inches below ground elevation for 25-year flows. Hydraulic Grade Lines and pipe velocities for the existing system and ultimate land use conditions can be viewed in the existing system StormCAD file in ***Appendix Q***; selected profiles are included in ***Appendix I***.

15.0 PROPOSED STORM DRAIN SYSTEM ALTERNATIVES

15.1 **Alternatives Considered.** Four different storm drain configurations and five detention options were analyzed as part of developing a local flood mitigation plan for the project area. The design goal is to develop storm drain configurations that meet DCM requirements for 25-year flow below top of curb, 100-year flow within the right-of-way, cross-intersection flow, clear width and 100-year HGL below ground elevation. The Annie

Street Storm Drain Improvements project was placed on hold for an extended time after the development of three alternatives and five detention options. During that time, the DCM was updated to reflect Alas 14 rainfall data. The first three alternatives as well as all detention options were evaluated with pre-Atlas 14 rainfall data. Alternative 4 was evaluated with Atlas 14 rainfall. None of the alternatives propose upgrades to the storm drain on South Congress Avenue since overflow/bypass from the system exits the project area. Upgrading the South Congress storm drain would bring additional stormwater into the project area. This is discussed in greater detail in Section 15.7. All four alternatives include the abandonment of storm drain running across private property from 304 W. Mary Street to Annie Street. Alternatives and options are summarized below. Exhibit A.4 in ***Appendix A*** includes schematic maps of the four alternatives and five options, an evaluation chart and HEC-HMS peak flow results for each of the scenarios.

During development of the first three alternatives, the maximum allowable pipe size that could penetrate existing roadway culverts was considered 42-inches. This determination was based on a review meeting with Pirouz Moin, PE from COA's Public Works Department. Mr. Moin reviewed record drawings for these bridges and developed a detail of reinforcement at the bridge that is necessary for a 42-inch pipe penetration. Larger storm drain outfalls were not anticipated at the time. During development of Alternative 4, ESD consulted with Karim Helmi, PE in December 2020 with the Quality Management Division on the possibility of connecting a larger diameter pipe to the existing bridge at Annie Street and Johanna Street. Mr. Helmi indicated that the larger pipe connections proposed in Alternative 4 are possible. He recommended the project team retain a subconsultant during the design phase to develop construction plans. The maximum outfall pipe size is approximately 7 to 9-feet tall and 12 to 14-feet wide based on space available in the right-of-way considering the roadway elevation grades and other existing utilities.

Curb inlet placement is the same for all four alternatives. The alternatives differ primarily in how the storm drain is routed to the creek. Alternative 1 includes two curb inlets that were removed from the project scope and not included in Alternatives 3 and 4. The inlets are located in the alley south of and parallel to Johanna Street and running from Wilson Street toward the east. The inlets capture runoff from drainage areas DA-A21-A.1, DA-

A21-A.2 and DA-A21-B. The inlets and associated pipe were removed from the project scope at a review meeting with WPD on June 29, 2017. Stormwater from the alley is conveyed through storm drain within easements to storm drain on Johanna Street as part of the Live Oak Condominium project (SP-2015-0460C).

15.2 **Alternative 1.** Alternative 1 splits the existing storm drain branch lines at the Mary Street and Newton Street intersection. From this intersection, one proposed line connects to WPD's Mary Street Emergency Relief Line and the other continues to a diversion structure at the Annie Street and Newton Street intersection. From the diversion, one line outfalls into East Bouldin Creek at Annie Street and a second outfalls to the creek at Milton Street. Additionally, a new system is added on Crockett Street to serve the area surrounding the Courtyard Condominiums. The system outfalls to the creek at Crockett Street. Finally, additional flow is routed to the existing system on Johanna Street that runs between Wilson Street and East Bouldin Creek; this is possible since the proposed system on Crockett Street captures flow that is routed to the Johanna Street line in the pre-project scenario. A short section of the existing Johanna Street storm drain is replaced as part of the flow routing revision. Detailed calculations for Alternative 1 are included Section 16 of this report.

Alternative 1 was analyzed with pre-Atlas 14 rainfall data. Alternative 1 would need to be evaluated with Atlas 14 rainfall data if it is selected as the preferred alternative.

15.3 **Alternative 1 Detention Options.** Several different detention options were analyzed with Alternative 1 in an effort to develop a flood mitigation plan for the neighborhood that would not include channel improvements. Detailed calculations for the detention options were reviewed with WPD on March 7, 2017. The following detention options were investigated.

- Option 1 – rain garden at Bartlett/Live Oak Streets
- Option 2 – Detention pond within existing right-of-way at Hodges Street
- Option 2B – Detention pond at Hodges Street with right-of-way acquisition to accommodate a larger pond
- Option 1&2 – Bartlett/Live Oak rain garden and Hodges Street detention pond in existing right-of-way

- Option 1&2B – Detention pond at Bartlett/Live Oak and larger Hodges Street detention pond with right-of-way acquisition

Appendix Q includes HEC-HMS models of the detention options that are paired with Alternative 1.

15.4 **Alternative 2.** Proposed Alternative 2 is similar to Alternative 1, but keeps the branch lines from Johanna and Mary Streets joined at the intersection of Mary and Newton Streets. From this junction, the storm drain system continues north on Newton Street, turns west on Annie Street and eventually outfalls into East Bouldin Creek at the Annie Street bridge. This configuration cuts off flow to WPD's 42-inch Mary Street Relief Line and leaves the line oversized. ***Appendix Q*** includes a StormCAD file of Alternative 2.

15.5 **Alternative 3.** The Alternative 3 storm drain configuration is most similar to the existing storm drain system. All proposed storm drain, except the Mary Street Relief Line, conveys stormwater to the creek at Annie Street. The total area draining to the creek at Annie Street is reduced by the area draining to the Mary Street sump inlets and captured by the Mary Street Relief Line. Curb inlet connections at Johanna and Wilson are modified slightly so that the Annie Street system captures more flow than in pre-project conditions. The creek flow decrease at Johanna Street mitigates for the creek flow increase associated with the Mary Street Relief Line. Detailed calculations for Alternative 3 were reviewed with WPD on June 17, 2017. ***Appendix Q*** includes StormCAD and HEC-HMS models for Alternative 3.

Alternative 3 was analyzed with pre-Atlas 14 rainfall data. Alternative 3 would need to be evaluated with Atlas 14 rainfall data if it is selected as the preferred alternative.

15.6 **Alternative 4.** Alternative 4 storm drain routes runoff from the Crockett Street neighborhood to the creek at Johanna Street through new pipes and upsized storm drain on Johanna Street west of Wilson Street. Runoff from the remaining area, minus area flowing to the Mary Street sump inlets, is conveyed to the creek at Annie Street. Existing storm drain is upsized on Annie Street, Newton Street, and Mary Street east of Newton. New storm drain is also added on Johanna east of Newton. Detailed Calculations for Alternative 4 are included in Section 17 of this report.

15.7 **South Congress Avenue.** Curb inlets and storm drain along the east side of South Congress Avenue are very undersized. As a result, storm water runoff backs up at the corner of South Congress Avenue and Mary Street, overtops the Mary Street crown and continues down the east South Congress Avenue gutter. As shown in the ***Appendix I*** inlet calculation spreadsheets, there is 127.2 cfs of over-capacity flow at this corner for the 100-year storm and 82.4 cfs for the 25 year storm (ultimate development conditions over-capacity flow for DA-11 plus DA-12). This excess runoff is captured by storm drain further downstream on South Congress Avenue and eventually outfalls to East Bouldin Creek near Lady Bird Lake. The flow pattern at South Congress Avenue and Mary Street is represented in the Pre-Project HEC-HMS model by Diversion-S. Any proposed upgrades to storm drain or inlets along South Congress Avenue would send more runoff to the Annie Street Storm Drain Improvements project area and less flow would continue down South Congress Avenue. Storm drain on South Congress is left in its existing configuration so that additional flow is not brought into the project area. The pre-Atlas 14 25-year floodplain exceeds the creek banks and encompasses numerous structures throughout the project area. Routing additional storm water runoff to the creek as part of the Annie Street Storm Drain Improvements is not recommended. The existing roadway culverts are another limiting factor even if channel improvements increase the creek capacity. The maximum storm drain outfall sizes are limited by geometry constraints of existing bridges and available right-of-way space. Areas for further investigation that pertain to upgrading the South Congress Avenue storm drain system between Mary Street and Live Oak Street are discussed in Section 18.6.

16.0 ALTERNATIVE 1 HYDROLOGY AND HYDRAULICS

16.1 **Alternative 1 Storm Drain Hydraulics.** An Alternative 1 storm drain system map, inlet calculations and street flow analysis are found in ***Appendix K***. Calculations follow the same procedures outlined in Section 14.0.

Alternative 1 has been evaluated using StormCAD Series 4 in the same manner described in Section 14.1. Proposed calculations use existing conditions street geometry data. Proposed Hydraulic Grade Line profiles are included in ***Appendix K*** and an electronic file is included in ***Appendix Q.*** Velocities for several pipes are slightly over 20 fps for the 25-year storm; this occurs in locations where proposed storm drain crosses existing wastewater lines or on steeper stretches near East Bouldin Creek. The proposed pipes with velocities over 20 fps are: PR-CO-158, PR-CO-162, PR-197 and storm drain on

Crockett Street near East Bouldin Creek. At the preliminary engineering stage, record drawings have been used to estimate existing wastewater line depths, but several of the lines are over 50 years old, and record drawing information is incomplete or missing. It is recommended resolving the velocity issue during design phase after potholing for existing utilities. Drop manholes could be considered to reduce the velocities on Crockett Street. A summary of existing wastewater line crossings and descriptions of available record drawing information is included in ***Appendix K***. Utility conflicts could result if the actual depth of existing utility crossings differs from the depth found on record drawings.

Proposed improvements to the existing Johanna Street storm drain system that runs from Wilson Street to East Bouldin Creek are based on WPD's StormCAD model of this line. The StormCAD file has been modified only where improvements are proposed near Wilson Street. The rest of the model remains unaltered and has not been reviewed by ESD.

The proposed design includes a storm drain system on the Live Oak Condominiums property at 211 W. Johanna Street. An approved Site Plans for this system are available from the Austin Build + Connect search engine filed under project no. SP-2015-0460C. (see ***Appendix K***). The proposed curb inlet in the alley between the Live Oak Condominiums and Courtyard Condominiums (300 Crockett Street) may require re-grading to effectively capture flow. There is a small earth berm along the north side of the alley that helps direct flow to the proposed curb inlet location; this would minimize required re-grading.

The inflow-diversion table for the diversion at the intersection of Annie and Newton Streets has been developed using CivilStorm. The Dynamic Wave solver is used to determine the flow to the Milton Street storm drain for a range of inflows. The Dynamic Wave solver solves the full momentum equation in one dimension.

Since a storm drain pipe and outfall is proposed on Milton Street in Alternative 1, the roadway has been analyzed to determine if curb inlets are needed. An estimate of the gutter flow depth is based on delineation of the area draining to the downhill end of Milton Street near East Bouldin Creek, 5-minute time of concentration and Rational Method C value equal to the highest C value for the project area. With these inputs, the depth of flow is below the top of curb for the 100-year storm. This meets DCM requirements for containing storm water runoff within the curb for 25-year storms and within the right-of-way for 100-year storms. Curb inlets are not needed on Milton Street. See calculations in ***Appendix K***. Additionally, Milton Street was not included in the AULCC evaluation since this outfall was not anticipated at the time of AULCC submittal.

Proposed Alternative 1 improvements include four separate storm drain systems that outfall into East Bouldin Creek. These systems can be constructed separately or as one large project. Phased channel improvements could be considered if the storm drain systems are constructed as separate projects.

16.2 **Pre-Project Creek Hydrology for Alternative 1.** The pre-project model developed for comparison to Alternative 1 is described in Section 11.

16.3 **Alternative 1 Creek Hydrology.** Alternative 1 creek hydrology is analyzed with HEC-HMS and represents flow patterns associated with proposed storm drain upgrades. Unless noted below, the same methods described in Section 11 are used to calculate model input parameters. Maps depicting the Proposed Alternative 1 basins and HEC-HMS model schematic are included in ***Appendix L***. Proposed lag time calculations, impervious cover values, diversion tables and storm drain system data are also included in ***Appendix L***.

Proposed storm sewer improvements result in revised flow patterns to East Bouldin Creek. Outflow from basin EBLDN-M and reach element “Annie Sys 1” are routed to East Bouldin Creek at Annie Street in the pre-project model. Some flow from these two elements is routed to other creek junctions in the Proposed Alternative 1 model through proposed storm drain. The flow pattern revisions for Proposed Alternative 1 are summarized below.

- The proposed storm drain system on Crockett Street adds area draining to the creek at Crockett Street. This is represented in the Proposed Alternative 1 HEC-HMS model by basin EBLDN-PR-1, which replaces EBLDN-A of the pre-project model. The area for EBLDN-PR-1 basin is the sum of area for EBLDN-A and the Crockett Street storm sewer system. This change is seen by comparing flows at

EBLDN-A in the pre-project model to flows at EBLDN-PR-1 in the Proposed Alternative 1 model.

- The existing storm drain system on Johanna Street captures flow from a smaller area in the proposed conditions. The proposed storm drain on Crockett Street reduces the area draining to this system. Reconfiguring the inlets at the corner of Wilson and Johanna Streets adds some new drainage area, represented by EBLDN-PR-2, but the net result of all proposed improvements is less area draining to East Bouldin creek at Johanna Street. This change is evident by comparing pre-project and Proposed Alternative 1 flows for the “Johanna Sys 1” HEC-HMS reach element.
- WPD’s Mary Street Emergency Relief Line adds area draining to the creek at Mary Street. In Proposed Alternative 1, basin EBLDN-PR-3 consists of area draining to the Mary Street Emergency Relief Line (part of EBLDN-M) as well as area flowing overland to East Boudlin Creek at Mary Street (EBLDN-I). This revision is evident by comparing flow from pre-project basin EBLDN-I to Proposed Alternative 1 basin EBLDN-PR-3 and noting the addition of reach element “PR Mary Sys 1”.
- The proposed storm drain significantly reduces the area draining to East Bouldin Creek at Annie Street. This change is evident by comparing pre-project basin EBLDN-M to Proposed Alternative 1 basin EBLDN-PR-5.
- The proposed storm drain routes some flow from the Annie Street storm drain system to Milton Street through a diversion structure at Annie Street and Newton Street. This is represented by PR-Diversion-1, which captures flow from EBLDN-PR-4. The change is seen by comparing pre-project flows for reach element “Annie Sys 1” to Proposed Alternative 1 flows for “PR Annie Sys 1” and noting the addition of reach element “PR Milton Sys 1”.

The diversion element PR-Diversion-R represents gutter flow at the corner of Wilson and Johanna Streets for the proposed conditions. Flow captured by the curb inlet at this location is routed to East Bouldin Creek at Johanna Street through proposed storm drain. Without proposed improvements, flow captured by this inlet is routed to the Annie Street storm drain system. This inlet is existing and will remain in the proposed conditions. Bypass flow is captured by the system that outfalls at Mary Street in the proposed scenario. The inflow-diversion table for proposed Diversion-R relates the peak HEC-HMS flow for EBLDN-PR-2 (Inflow) to the curb inlet bypass flow (Diversion) for corresponding return periods.

There is one new diversion in the proposed conditions HEC-HMS model. PR-Diversion-1 represents the splitter box at the intersection of Annie and Newton Streets. This is where the storm drain splits and routes flow to East Bouldin Creek along Annie Street or Milton Street. The inflow-diversion table for this element is the same rating curve used in the Proposed Alternative 1 StormCAD model. The inflow-diversion table for the StormCAD diversion link has been developed using CivilStorm's Dynamic Wave solver. This solver is used to determine the flow to the Milton Street storm drain for a range of inflows. The Dynamic Wave solver solves the full momentum equation in one dimension.

Proposed storm sewer data has been added to the HEC-HMS model as needed to reflect proposed storm sewer improvements and re-route flow to the appropriate location or outfall. The storm drain data has been simplified to input into HEC-HMS. For example, pipes with the same diameter and similar slopes are averaged into one HEC-HMS reach element. These calculations are included in ***Appendix L***, Exhibit L.8 through Exhibit L.11.

Proposed Alternative 1 HEC-HMS model results show that peak flows increase at the Crockett, Johanna and Mary Street junctions with East Bouldin Creek, but decrease at the Annie Street junction. The maximum flow increases at Crockett Street is 1.41% and 1.59% at Mary Street. Flow increases at Johanna Street are below 1% of existing. See Exhibit L.14 in ***Appendix L***. The increased flows are due to proposed outfalls into East Bouldin Creek at Crockett and Mary Streets. Distributing flow along East Bouldin Creek at several discharge points as opposed to one outfall at Annie Street results in decreased flow at Annie and Milton streets. The Annie Street and Mary Street junctions both experience peak flow at 12:27 in the pre-project and Proposed Alternative 1 models. A review of the flow data at 12:27 shows that when flow increases at the Crockett and Mary Street junctions due to proposed creek outfalls, there is a corresponding decrease at the Annie Street junction. The flood wave at Annie Street has been attenuated enough to also mitigate the impact of a proposed storm drain outfall at Milton Street. This is illustrated in a table of flow data at 12:27 for junctions and their contributing elements for 100-year existing land use conditions, which is included in Exhibit L.15 in ***Appendix L***. A table of peak flow values is also included for comparison. The red arrows on these charts indicate how flow is re-distributed for the proposed conditions.

16.4 **Alternative 1 Creek Hydraulics.** The Proposed Alternative 1 HEC-RAS model is identical to the pre-project model discussed in Section 13 except that flow data is from the Proposed Alternative 1 HEC-HMS model. Flow change data and a comparison between pre-project and Proposed Alternative 1 water surface elevations are included in ***Appendix M***. The water surface elevation rises between Live Oak Street and Milton Street by a maximum of 0.08 feet for existing land use conditions and all storm events. This rise occurs during the 2-year storm event at cross-section 10284. The water surface elevation for this same section rises by a maximum of 0.09 feet for ultimate development land use conditions. This occurs during the 2-year storm event at cross-section 10284.

There are also several locations outside the project area that the water surface increases by 0.01 feet for different storm events and land use conditions. The first occurs at cross-section 13447 for the 2-year storm event and existing land use conditions. This is just downstream of the Gillis Park pedestrian bridge. Downstream of the pedestrian bridge, there is no change in water surface elevation for 2,446 feet at which point the water surface starts to rise due to proposed storm drain on Crockett Street. The second location is at cross-section 8022 for the 25-year storm and ultimate development conditions. This is between the Elizabeth Street and South First Street bridges. There is no rise in water surface elevation between this cross-section and Mary Street, which is approximately 2,000 feet upstream. The final location is cross-section 7704 for the 10-year storm and ultimate development land use. This is just downstream of the South First Street bridge. Again, the water surface elevation does not rise until the Mary Street bridge, which is approximately 2,500 feet upstream. The water surface rise for these specific cases is not considered a result of proposed improvements, but rather an anomaly of the HEC-RAS program. Bridge calculations can result in slight and isolated instances of water surface elevation change between models due to the regime shift between open channel calculations (energy equation) and bridge section calculation (momentum equation). Possible modeling solutions include adding cross-sections, moving cross-sections or refining the computation tolerances. It is recommended evaluating all cross-sections with

0.01 foot rise downstream of Monroe Street for association with modeling software anomalies.

16.5 **Alternative 1 Creek Impact Analysis.** Channel improvements are proposed for East Bouldin Creek between Fletcher Street (one block upstream of Live Oak Street) and W. Elizabeth Street to mitigate for the Proposed Alternative 1 storm sewer improvements. Improvements consist mainly of widening the channel and are shown in the Proposed Channel Improvements HEC-RAS model. There is no rise in water surface elevation between the pre-project and Proposed Channel Improvements HEC-RAS models for the project area. The channel Manning's n value is changed from 0.045 to 0.030 for cross-section 10203. This could be achieved by clearing dense brush from the channel banks and lining the channel with rock rubble or stacked limestone blocks. See map and cross-section details in ***Appendix M*** Exhibit M.4 and creek photos in ***Appendix O***.

In general, channel velocities increase minimally between the pre-project conditions and Proposed Channel Improvements. The maximum increase for the 100-year storm event is 0.67 feet per second. Although the increase is minimal, existing velocities in the channel are higher than 6 feet per second for a number of cross-sections. Effective model velocities are summarized in ***Appendix M*** Exhibit M.5 for the 100-year profile along with velocities from the pre-project, Proposed Alternative 1 and Proposed Channel Improvement models.

16.6 **Alternative 1 Creek Impact Mitigation.** The following items should be addressed during design phase.

- The need for erosion protection should be evaluated for the creek segment within the project area.
- Coordination with WPD's stream restoration group should continue regarding new outfalls into East Bouldin Creek and known erosion sites. A field visit with Janna Renfro, P.E. should be scheduled early in design phase.
- Survey should include East Bouldin Creek since creek geometry appears to have changed since the 2005 Effective HEC-RAS model was completed. Consider known erosion sites, large trees, structures and changes in channel conditions when defining survey cross-section locations.

- Channel improvements needed to mitigate the effects of high existing channel velocities could be necessary; these improvements are not part of the Proposed Channel Improvements model.
- There is an existing outfall just downstream of the Live Oak Street bridge on the west bank that may require upgrades.
- There is an existing wastewater manhole in the creek just upstream of Johanna Street that has experienced some erosion and may require improvement. See photos in ***Appendix O***.
- Implement HEC-RAS modeling solutions for isolated cross-sections that rise by 0.01 feet outside the project area.

16.7 **Alternative 1 Feasibility.** WPD's Streambank Stabilization Program reviewed the Alternative 1 creek improvements in June 2016 and recommends only pursuing creek modification after exhausting all other feasible options. The reasons for avoiding channel widening include:

- While there are some areas of the creek within the project area that exhibit erosion, many areas have stabilized and would be disturbed in the proposed improvements. Conversely, eroded areas could be further destabilized.
- It seems like many of the cross-section changes are very minor vertical excavations (most < 1', all < 2'). Would the revised cross-section simply restore itself over time with deposition? How would these very small excavations be stabilized?
- There would be significant tree impacts, including heritage trees.
- It is likely that channel widening would need an Individual Permit from the US Army Corps of Engineers. This is a significant undertaking and may mean costly mitigation.
- It appears that easements are scattered throughout this stream reach. Easement acquisition should be considered in terms of time and cost.
- Reducing roughness by removing vegetation, will require on-going maintenance and could have adverse impacts to channel stability.

17.0 ALTERNATIVE 4 HYDROLOGY AND HYDRAULICS

17.1 **Alternative 4 Storm Drain Hydraulics.** Proposed Alternative 4 storm drain configuration is shown in maps in ***Appendix S***. Proposed improvements include two separate storm drain systems. One system serves the area surrounding the Crocket Street condominiums and outfalls to East Bouldin Creek at Johanna Street. A second system outfalls at Annie Street and captures all the remaining area originally draining to the creek at Annie Street, with the exception of area draining to the Mary Street sump inlets. The Mary Street Relief Line was constructed in late 2020 and captures runoff from the Mary Street sump area. The Mary Street Relief Line was constructed as an interim phase and utilizes the existing storm drain across private property as overflow capacity. The existing storm drain connection at the upstream end of the Mary Street Relief Line as well as the storm drain across private property will be abandoned as part of Alternative 4. Alternative 4 includes adding a curb inlet and short section of pipe to the upstream end of the Mary Street relief line. The inlet is needed to meet DCM street flow requirements. Stormwater flowing to the intersection of Mary and Newton Streets is routed through proposed storm drain on Newton and Annie Streets. The Mary Street Relief Line fully conveys runoff from the Mary Street sump area. The Mary Street Relief line was constructed with a restrictor plate that directs overflow runoff to the storm line on private property. The restrictor plate can be removed at the end of construction since the overflow capacity provided by the existing line across private property will no longer be needed.

Proposed Alternative 4 pipes were designed with StormCAD Connect software. Inlet capture values from inlet calculation tables were entered into StormCAD as Flow (Additional Subsurface) in the System Flows tables. Inlet calculations are based on peak flow values calculated using the Rational Method and Atlas 14 rainfall intensities. Rainfall intensities were calculated using DCM Equation 2-1 and coefficients from Table 2-2A for Zone 1. As noted in DCM Section 5.5, the use of coincident frequencies is not encouraged. As a result, the method is not used to determine tailwater elevations in the Alternative 4 StormCAD model. According to Watershed Engineering Division, pre-Atlas 14 models can be used as an approximation of Atlas 14 scenarios. The pre-Atlas 14 100-year rainfall approximates Atlas 14 25-year rainfall and pre-Atlas 14 500-year rainfall approximates Atlas 14 100-year rainfall. The 100-year Effective HEC-RAS model water surface elevation is used for the tailwater elevation in 25-year Alternative 4 StormCAD model. The 500-year Effective HEC-RAS model water surface elevation is used for the tailwater elevation in 100-year Alternative 4 StormCAD model. Correspondence with Watershed Engineering Division regarding the use of pre-Atlas 14 models is included in ***Exhibit G.17***. Inlet Calculations and StormCAD profiles are included in ***Appendix S***. The inlet calculation spreadsheets include columns that show compliance with DCM requirements for street ponded width 25-year runoff below the curb and 100-year flow contained within the right-of-way. Several slight variations from these requirements will be addressed during design phase when survey data can be used to calculate more accurate results. Shifting inlet placement is expected to resolve any issues. StormCAD models are included in ***Appendix Q***

17.2 **Pre-Project Creek Hydrology for Alternative 4.** A second Pre-Project HEC-HMS model was created in October 2020 for comparison to Alternative 4 improvements. The Pre-Project HEC-HMS model represents conditions before the Mary Street Relief Line was constructed. Maps of October 2020 pre-project HEC-HMS basins and elements as well as input data calculations and are included in ***Appendix R***. Unless noted below, calculation methods are the same as described in Section 11.

Pre-project drainage areas were delineated in a manner that reflects proposed Alternative 4 drainage areas. Pre-project times of concentration and reach lag times are based on existing pipes and/or existing gutter flow wherever proposed pipes replace existing pipes or where storm drain is added to streets without existing storm drain. Pre-project sub-basin areas were delineated so that a proposed HEC-HMS model could be created from the pre-project model by changing how sub-basin outflow is routed to the creek; sub-basin areas are the same in the pre-project and proposed HEC-HMS models. Pre-project sub-basin outflow is routed to the creek through gutters and existing storm drain. Proposed sub-basin outflow is routed to the creek through proposed storm drain. HEC-HMS reaches representing existing pipes or gutter were modeled with the Lag routing method. The pipe travel (lag) time was calculated from the Storm CAD pipe flow time for the 100-year Atlas 14 storm. The gutter travel (lag) time was calculated from the following gutter flow calculation found in Hydrologic Analysis and Design by Richard McCuen, p. 143:

$$\boldsymbol{V = k(S)^{0.5}}$$

Where,

V = velocity (feet per second)
S = slope in (ft/ft)
k = 46.3 as found in Table 3-14

The remaining HEC-HMS input values were calculated as described in Section 11.

Two HEC-HMS diversions, located on Live Oak Street at Newton and Eva Streets, represent overflow stormwater runoff from Live Oak Street entering the project area. The storm drain on Live Oak Street was analyzed using CivliStorm software and was shown to be undersized. Additionally, some of Live Oak Street slopes toward the project area and, where a crown is present, street flow calculations show that gutter flow depths exceed the street crown depth. The result is that stormwater is not fully captured by the storm drain system on Live Oak Street. Runoff not captured by the storm drain system follows the surface contours and flows partially downstream on Live Oak Street and partially into the project area via Eva and Newton Streets. The diversion tables were developed based on Lidar contours and divides flow based on the potential downstream paths for stormwater overflow at Live Oak and Eva or Live Oak and Newton. Overflow at Live Oak and Eva can flow to the east Eva Street gutter, the west Eva Street gutter or the north Live Oak Street gutter. The diversion table sends two thirds of the inflow to Eva Street and one third to the north Live Oak Street gutter. Similarly, the diversion at Live Oak Street and Newton diverts flow based on the Lidar contours. The Newton diversion table sends one half of the inflow to Newton Street and one half to the Live Oak north gutter.

The City of Austin recently updated design rainfall requirements to reflect Atlas 14 rainfall data. The DCM currently requires a frequency storm based on Atlas 14. However, the Effective HEC-HMS model, which is the basis for the project models, pre-dates this change. The Effective HEC-HMS model uses the SCS storm, as described in Section 11. Watershed Engineering Division allows the 500-year SCS storm with pre-Atlas 14 24-hour rainfall depths as a substitution for Atlas 14 100-year analysis. The 500-year storm is included in the October 2020 pre-project and proposed Alternative 4 HEC-HMS models. Correspondence with Watershed Engineering Division is included in ***Appendix G***.

17.3 **Proposed Creek Hydrology for Alternative 4.** The proposed Alternative 4 HEC-HMS model represents the scenario after construction of the Mary Street Relief Line and Alternative 4 improvements. Future sidewalks are not included in the impervious cover calculations for the Alternative 4 HEC-HMS model. Further analysis would be needed if sidewalks are included in the project. A map of Proposed Alternative 4 HEC-HMS elements is included in ***Appendix T*** as well as input data calculations. The revisions between the pre-project and proposed Alternative 4 HEC-HMS models include:

- Proposed storm drain replaces gutter flow in the Crockett Street area.
- Proposed storm drain replaces existing storm drain on Annie Street, Newton Street (from Annie to Johanna) and Johanna Street (from Newton to the creek).

Proposed Alternative 4 HEC-HMS results are summarized in comparison to pre-project HEC-HMS results in ***Appendix T***. Proposed improvements result in less than 1% increase in peak flow at the creek junctions. The need for erosion protection in the creek, particularly at the downstream edge of existing roadway culverts, should be evaluated during design phase. Erosion protection should maintain the creek's cross-sectional area and be constructed with materials having a similar roughness to the existing creek. Erosion protection would not need to be added to the HEC-RAS model. Energy dissipators are not recommended based on a site visit conducted by WPD's streambank stabilization group on March 8, 2021,

17.4 **Alternative 4 Feasibility.** A map of Alternative 4 storm drain pipe sizes and necessary utility relocations is included in ***Appendix T***. Proposed storm drain outfalls into the creek at Annie and Johanna Streets are routed through existing roadway box culverts. Both roadway culverts have existing storm drains through the culvert walls, although the proposed pipes are larger than the existing pipes. A preliminary structural review of the culverts and proposed pipes indicates that penetrating the roadway culvert walls with larger proposed storm drain is feasible. A structural concrete wall would be constructed on the outside of the roadway box culvert and around the proposed storm drain pipe. This wall would be doweled to the existing roadway culvert. Alternative 4 does not require creek modifications if WPD accepts the less than 1% increase in peak flow rates at the HEC-HMS creek junctions. HEC-RAS modeling was not performed for Alternative 4.

WPD's streambank stabilization group conducted a site visit on March 8, 2021 to assess the creek condition within the project area. Severe erosion was not observed at the Annie or Johanna Street outfalls to the creek. Energy dissipators are not recommended for the minimal increase in flow. Erosion protection could be needed if new erosion is discovered during design phase.

A heritage tree is located on the east creek bank just north of the Annie Street roadway culvert. The tree's critical root zone may extend into the proposed storm drain trench area. The City arborist should be contacted during design phase to evaluate project area trees and provide recommendations. The construction contract should specify hand-digging through the critical root zones. A picture of the heritage tree at Annie Street and the creek is included in ***Appendix O*.**

18.0 RECOMMENDATIONS AND PROJECT DELIVERY

18.1 **Alternative Recommendation.** ESD recommends Alternative 4 to address localized flooding and bring the storm drain system infrastructure up to current Drainage Criteria Manual standards. Alternative 4 benefits include:

- Mitigation of local flooding due to runoff from the right-of-way.
- The project area is upgraded to meet current DCM level of service standards.
- The storm drain running across private property is abandoned.
- Restrictor plate on Mary Street Relief Line is removed.
- Less than 1% peak flow increase at the creek.
- Smaller storm drain on Annie Street than Alternative 3.
- Minimal creek work to install erosion protection does not require an individual US Army Corps of Engineers permit. Minimal creek work is covered under the nationwide permit.
- The design includes two separate storm drain systems that can be constructed in phases, allowing for budget planning flexibility.
- The opportunity for partnering with Austin Water to include water and wastewater upgrades with the storm drain improvements and share certain costs.

Key points that informed the selection of Alternative 4 as the recommendation are summarized below and presented in Exhibit A.4.

- Alternative 1 is less preferred due to the associated channel improvements.
- Alternative 1 detention options do not adequately compensate for peak flow increases at the creek, cannot be constructed within existing right-of-way or are impractically large.
- Alternative 3 peak flow increases at the creek are less than 1%, but Alternative 3 is less preferred due to larger storm drain pipe sizes.
- Alternative 2 analysis was removed from the PER scope by WPD. It is not recommended investigating Alternative 2 further since peak flows at Crockett Street are expected to be higher than 1%, similar to Alternative 1.

18.2 **City of Austin Permitting.** It is recommended pursuing a General Permit that includes additional drainage and floodplain review by WPD as opposed to a Site Development Permit. The Site Development permitting process is longer, geared toward private development and includes reviews that are not applicable to this project. The permitting phase duration would be shorter with a General Permit. The General Permit Program Office (GPPO) and the City's Environmental Officer should be contacted early in design to coordinate adding floodplain, environmental and drainage review components to the permit process. An Environmental Resource Inventory should be completed before meeting with the Environmental Officer. This modified General Permit process has been used on previous ESD creek work projects, but GPPO could require that the project is permitted under the Site Plan process. ESD recommends that the project sponsor assume site plan permit durations for the purpose of scheduling.

The Floodplain Office is not opposed to a modified General Permit process and has the following recommendations:

- There should be 3 or fewer supplemental reviews.
- Supplemental reviews should be added to the AMANDA permitting tracking software. Reviews in AMANDA are completed within certain timeframes. Review requests outside of AMANDA are completed when the reviewers have extra time.
- Floodplain submittals through a modified General Permit process should still follow all the requirements of Site Plan submittals (completeness check, etc.).

- Site Plan reviewers should conduct reviews associated with the Critical Water Quality Zone. The reviews should be coordinated with the Environmental Officer early in design phase.

Coordination will also be needed with the following City of Austin entities:

- WPD – regarding wetland mitigation at the Johanna Street outfall.
- WPD – regarding the FEMA Physical Map Revision for East Bouldin Creek
- DAPZ – Special Even Calendar coordination and meeting attendance prior to and during construction
- ROW Management – coordination prior to construction and permits during construction
- Street and Bridge – coordination for protected streets and upcoming maintenance. The intersections of Eva/Mary and Eva/Johanna are protected until June 28, 2021. The intersections of Mary/South Congress and Crockett/South Congress are protected until October 4, 2030. Data Mart does not currently show planned maintenance in the project area, however, several road segments are rated “poor” or “failed” and may need extra coordination regarding trench repair.
- City Arborist – regarding heritage trees within the project area.

18.3 **Phase I Environmental Assessment.** Securing a Phase I Environmental Assessment is recommended even though the proposed improvements are within existing right-of-way or easements in a highly urbanized neighborhood, there are documented underground storage tanks near the area.

18.4 **Federal Emergency Management Agency.** Watershed Engineering and the City’s Floodplain Office concur that Alternative 4 meets the City of Austin’s No Adverse Impact guidelines. Watershed Engineering does not require Physical Map Revisions (PMR), Letters of Map Revision (LOMR) or Conditional Letters of Map Revision (CLOMR) for projects that meet the No Adverse Impact guidelines.

Watershed Engineering Division has begun the process of updating the effective hydrologic and hydraulic models for East Bouldin Creek based on Atlas 14 rainfall. FEMA floodplains are based on these models. A consultant will begin the floodplain study and process of submitting a Physical Map Revision to FEMA in Spring 2021. Watershed Engineering recommends evaluating changes associated with the Annie Street Storm Drain Improvements in the consultant's study.

A No Adverse Impact certification sealed by a Texas Professional Engineer is required for permit submittal.

18.5 **US Army Corps of Engineers.** Minor creek work associated with proposed storm drain outfalls meets the requirements for a general, or nationwide, permit under Section 404(e) of the clean Water Act. The permit is administered by the US Army Corps of Engineers. Nationwide Permit 7 for "outfall structures and associated intake structures" requires that the owner submit a pre-construction notification and comply with the National Pollutant Discharge Elimination System Program.

18.6 **Design Phase.** The following issues should be addressed or investigated further during design phase:

- The Mary Street Relief Line's restrictor plate should be removed at the end of construction for the system outfalling at Annie Street.
- Final design for storm drain at the Live Oak Condominium development (211 W. Johanna Street).
- The potential need for erosion protection in the creek, particularly at the downstream edge of existing roadway culverts.
- Street and Bridge Division roadway maintenance plans. Proposed inlet calculations may need to be revised if the street cross-section changes.
- Structural design of the support walls where proposed storm drain connects with existing roadway culverts.
- Consideration should be given to using drop manholes near East Bouldin Creek to reduce velocities for these steep stretches.
- Consider adding debris fins to the existing box culverts. Debris fins are described in Hydraulic Engineering Circular No. 9. Anecdotal evidence gathered during field investigation indicates that the existing box culverts have previously clogged with debris during larger storm events.

- Potential addition of infill sidewalk or other Complete Streets components to the project scope.
- Permitting items noted in Section 18.2.
- Existing wastewater crossing depths are estimated based on record drawing information that may not be accurate. Specifically, there is low or very low confidence in the record drawings for Crossings 12, 13 and 14. See ***Exhibit K.6***.
- Include Live Oak Street in Survey area so overflow from Live Oak Street can be evaluated with survey data.
- Consider modeling the existing and proposed scenarios with 2D Integrated Catchment Modeling software (InfoWorks ICM) in order to quantify the number of structures that would benefit from the project.
- The construction contract should specify hand digging through the critical root zone of trees. Confirm hand-digging locations with the City Arborist.

18.7 **Potential Future Projects.** There are several concepts that could make it possible to upgrade the storm drain along South Congress Avenue. A detention pond at the vacant Hodges Street right-of-way would reduce peak flow from the existing Live Oak Street storm drain system and potentially provide more capacity in East Bouldin Creek for flow from South Congress Avenue. Detention on Lively Middle School campus would detain peak flow from campus property and provide capacity in the downstream storm drain for flow from South Congress Avenue. In all cases, downstream flooding along East Bouldin Creek must be considered. South Congress Avenue is protected throughout the project area until October 4, 2030.

18.8 **Project Phasing.** The proposed storm drain could be constructed as one project or in phases. Recommended project phasing for Alternative 4 is summarized below. Phasing is an option that could help with funding planning. Constructing only one phase is not recommended.

Project Phasing and Duration

Storm Drain Description	Recommended Construction Sequence	Estimated Construction Duration (Months)
Crockett Street Neighborhood	Phase 1	21
System outfall at Annie Street	Phase 2A	16
Modifications to Mary Street Relief Line	Phase 2B	1
Total Duration		**38**

18.9 **Preliminary Construction Cost Estimates.** Preliminary Class 4 construction cost estimates have been prepared for all proposed improvements. Tables below summarize proposed improvements and cost by construction phase. Detailed construction cost estimates are included in ***Appendix N***. Unit cost data has been compiled from the average bid price spreadsheets published by COA's Contract Management Division on the website: https://www.austintexas.gov/page/average-bid-prices. Data is from November 27, 2007 through FY 2018. Unit prices have been adjusted for inflation as needed. The storm drain improvement costs shown below include the cost to relocate water and wastewater lines that conflict with Alternative 4 storm drain. The storm drain improvement cost estimate does not include potential cost sharing with Austin Water. WPD would realize cost savings if Austin Water chooses to partner with WPD for water and wastewater upgrades within the project area. WPD and Austin Water would share common bid items, such as traffic control and mobilization, based on the linear feet of pipe placed by each utility. A map in Appendix N shows the water and wastewater line relocations that are necessary for Alternative 4. The map also shows relocations that would be funded by Austin Water if Austin Water chooses to partner with WPD.

Conditions that could make this project more costly than average include congested streets, narrow streets, maintaining access to businesses, South Congress area events, excavation through rock and any flooding along East Bouldin Creek. Additional creek stabilization outside the scope of study that may be needed to address existing erosion issues or high existing channel velocities is not included in the estimate. Constructing the project in separate phases could result in higher mobilization and/or traffic control costs.

Storm drain cost estimates include full roadway width pavement mill and overlay. The proposed pipe trenches are wide compared to the street widths and trench repair would leave the streets in poor condition. Most roads with proposed storm drain are currently scored B (good condition) or C (fair condition) and two blocks are scored D (poor condition). Edge milling and overlaying pavement over the existing center pavement would eliminate the center surface milling cost. However, this would change the street cross-section and would require modification to inlet calculations. Street and Bridge should be consulted early in design phase regarding proposed pavement plans and trench repair on road segments rated "poor" or "failed".

This project represents an opportunity to add Complete Streets components to existing streets in the project area. Estimated construction costs are provided for infill sidewalk and ramps along the proposed storm drain alignment. Public Works should be contacted regarding cost sharing.

Summary of Recommended Storm Drain

Phase	Description of Improvements	Pipe Length LF
Phase 1	Crockett Street Neighborhood	3,130
Phase 2A	System outfall at Annie Street	3,150
Phase 2B	Modifications to Mary Street Relief Line	100
	TOTAL	**6,380**

Preliminary Construction Cost Estimate – Storm Drain Improvements

Sponsor Department: Watershed Protection		
Phase	**Description of Improvements**	**Estimated Construction Cost (millions)***
Phase 1	Crockett Street Neighborhood	$ 2.86
Phase 2A	System outfall at Annie Street	$ 2.82
Phase 2B	Modifications to Mary Street Relief Line	$ 0.06
	TOTAL	**$ 5.73**

*Includes 30% contingency. Does not include cost sharing with Austin Water.

Preliminary construction costs for water and wastewater upgrades in the Annie Street neighborhood are summarized in the tables below based on the map in ***Appendix E***. Combining water, wastewater and storm drain upgrades in the same construction contract would allow for cost sharing between Austin Water and Watershed Protection Department. Costs for common bid items, such as mobilization and traffic control, would be shared based on the length of pipe for each utility as a percentage of total pipe. Watershed would see a cost savings of approximately $0.53 million if Watershed and Austin Water partner for utility rehabilitation in the project area.

Preliminary Construction Cost Estimate – Water and Wastewater

Sponsor Department: Austin Water	
Description of Improvements	**Estimated Construction Cost (millions)***
Water system improvements	$ 1.80
Wastewater system improvements	$ 1.32

*Includes 30% contingency and assumes common bid item costs are shard with WPD.

Preliminary Cost Estimate – Sidewalk

Sponsor Department: Public Works (Sidewalks and Special Projects)		
Sidewalk Locations:		
	Newton Street from W. Annie to Johanna	
	Newton Street from Crockett to W. Live Oak	
	Eva Street from Crockett to W. Live Oak	
	Total sidewalk quantity	**1,500 SF**
	Total Construction Cost Estimate*	**$ 135,000**
	Soft Cost Contribution	**$ 15,000**
	Total Project Cost Estimate	**$ 150,000**

*Based on an $18/SF unit cost that was provided by the Sidewalk and Special Projects Division.

18.10 **Engineering News Record's Construction Cost Index.** Engineering News Record's Construction Cost Index (CCI) can be used in the future to update Class 4 preliminary construction cost estimates provided in this report. Cost estimates can be updated using the formula and index values provided below. A Class 4 cost estimate updated by this method should be considered a Class 5 estimate.

$$future\ Class\ 5\ cost\ estimate = future\ CCI\ value \times \frac{Class\ 4\ cost\ estimate}{CCI\ value\ at\ the\ time\ the\ Class\ 4\ estimate\ was\ prepared}$$

Preliminary Construction Cost Estimate	Class 4 Estimate Location	Construction Cost Index (CCI)	Index Date
Lively Middle School Rain Gardens	Appendix F	10039	June 2015
Live Oak Street Rain Gardens	Appendix F	9116	September 2011
Proposed Storm Drain	Appendix N	11750	2021
Proposed Sidewalk	Appendix N	11750	2021

18.11 **Life Cycle Cost Analysis.** Life cycle costs include the cost of replacing project components that have a lifespan less than the project design life as well as maintenance costs. The main component of the proposed storm drain systems is reinforced concrete pipe. The USACE's Engineer Manual (EM 1110-2-2902) estimates the service life of concrete pipe is between 70 and 100 years. The proposed storm drain systems have been designed based on the peak flow rates for the sub-basins. A major component of peak flow calculations is the ultimate development percent impervious cover as determined based on the FLUM and maximum impervious cover allowed by current zoning. Assuming no change in land use, zoning impervious cover limits, time of concentration or rainfall intensities, the storm drain system design life can be approximated by the time it will take for the actual percent impervious cover in the project area to reach the ultimate development percent impervious cover. Discussion with the Planning and Zoning Department staff indicate that the FLUM could be updated as often as every 5-10 years. However, much of the project area is single family lots, which are the least likely to change land use. The other major land use in the project area is commercial, which already allows 95% impervious cover. It is difficult to quantify how fast impervious cover will increase in the future, but it can be approximated using building footprint shapefiles available from Data Mart. The building footprint area in the East Bouldin Creek neighborhood increased between 1987 and 2006 by approximately 0.23% to 0.29% per year. Applying this rate of increase linearly to the existing percent impervious (55%) cover and solving for the time it will take to reach the ultimate development percent impervious cover (77.5%) yields between 74 and 93 years. Component replacement costs are not included in the life cycle analysis since the design life approximates the lifespan of the project components.

WPD Field Operations crews inspect all curb inlets and manholes on a 2-year cycle and perform maintenance as needed. Typical maintenance includes flushing curb inlets and manholes. John Hayes with Field Operations estimated that it can take a 2-person crew between 2 and 5 days to flush a manhole. Inlet flushing is much easier and can be completed in several hours. A table included in ***Appendix N*** details the approximate costs for manhole flushing.

Total life cycle costs for proposed storm drain are based on an approximate 75-year design life. Life cycle calculations below assume 25% of the manholes in each storm drain system are flushed during a 2-year maintenance cycle.

Life Cycle Cost Estimate – Storm Drain Improvements

System Outfall Location	Number of Proposed Manholes	Number of Manholes flushed during 2-year Maintenance Cycle*	Annual Manhole Flushing Cost (low estimate)**	Annual Manhole Flushing Cost (high estimate)**
Johanna Street (Phase 1)	14	3.5	$4,154	$10,385
Annie Street (Phase 2A)	13	3.25	$3,857	$9,643
Total Annual Maintenance Cost			**$8,011**	**$20,027**
Design Life Estimate				**75 years**
Total Life Cycle Cost Estimate (low estimate)***				**$600,818**
Total Life Cycle Cost Estimate (high estimate)***				**$1,502,044**

*Assume 25% of manholes are flushed during a 2-year maintenance cycle

** Annual cost = (# manholes flushed during 2-year cycle) x (flushing cost/per manhole) ÷ 2

*** Total Life Cycle Cost = Total Annual Maintenance Cost x 75