Increasing the Safety of Hays County Citizens and First Responders through Hydrologic Data and Low Water Crossing Monitoring

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Acronyms

HRAP Hydrologic Rainfall Analysis Projection

USGS United States Geological Survey

NWS National Weather Service

TDMA Time-division multiple access

ALERT2 Automated Local Evaluation in Real Time

SDI12 Serial Digital Interface at 1200 baud

GOES Geostationary Operational Environmental Satellite

TWDB Texas Water Development Board

RAWS Remote Automated Weather Station

EOC Emergency Operations Center

Introduction

From a meteorological/hydrologic standpoint, 2015 was a historical year for Hays County, Texas. Hays County witnessed two historical flooding events within five months of each other with each event wiping out critical County infrastructure, damaging the auxiliary spillways of our flood protection dams, sweeping away homes, leaving many displaced and causing the loss of life.

During these events, Hays County and other jurisdictions relied heavily on the United States Geological Survey (USGS) gages, the County's low water crossing system, and reports from citizens to grasp the true scope of the floods. However, USGS gages washed away and the low water crossing system failed to provide and fulfill the data needs for Emergency Managers and those responding. The tragic events in 2015 changed the way Hays County viewed hydrologic data collection and the dissemination platforms. These events gave Hays County a unique opportunity to look for new and improved ways to provide officials and responders with more effective and efficient hydrologic/meteorological public safety data.

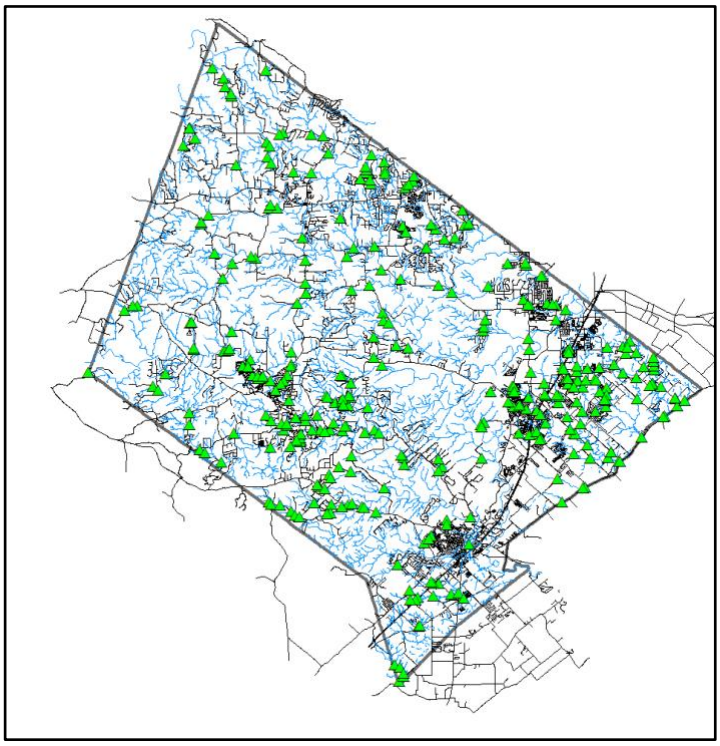


Figure 1. Hays County Low Water Crossings

Scope

After the devastating floods of 2015, Hays County took an in-depth look at the current flood warning and hydrologic data capabilities within the County to come up with a better way to monitor flood events and subsequently warn the citizens. This assessment was an iterative process that involved collaboration with subject matter experts, reviewing studies, and assessing the needs of the community. Through this internal assessment three key findings were identified:

- The current flood warning system lacked the ability to monitor stream conditions in the upper Blanco basin as well as throughout the County and its ephemeral streams;
- The current flood warning system ineffectively monitored the low-water crossings and failed to provide usable hydrologic data and as well as gather important reservoir conditions in the five detention basins that surround the City of San Marcos and;
- Gaps in the precipitation-monitoring infrastructure, which feeds back into the National Weather Service.

Based on the internal assessment and review of the Hays County After Action Report on the floods of 2015, Hays County began to accept bids to find a vendor that would implement a new flood warning system and low water crossing network.

Overview

Hays County is unique in that we are one of the fastest growing counties in the United States despite residing within Flash Flood Alley. Residing within the Flash Flood Alley presents a multitude of issues, concerns, and challenges that make proper flood monitoring essential. The County is cognizant of the rapid rate of development in the unincorporated parts of the County, the subsequent increase in traffic counts along our roads, and the increasingly large amount of those visiting the Hill Country.

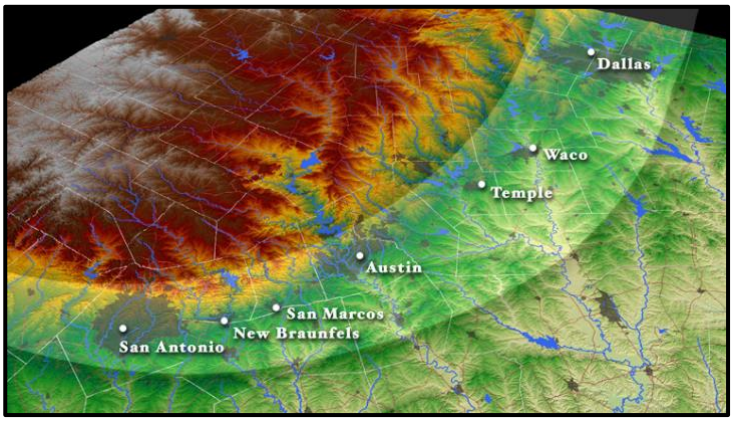


Figure 2. Flash Flood Alley

Hays County completed the *Hays County Low Water Crossing Urgency Rating* study, which examined every low water crossing and stream within Hays County. Upon completion of the study, a comprehensive report was developed, rating all of the low water crossings based on their safety risk. The data utilized to calculate the safety risk rating included; traffic counts, inundation of the road at various flood frequencies, and what flood frequencies would it take to top the road. The calculated risk rating played an instrumental role in the placement of the new flood warning infrastructure and the implementation of road improvement projects.

Hays County has over 200 low water crossings that cross streams of all sizes. These streams range from the size of the Blanco River, to Onion Creek, to large drainage ephemeral streams to small/dry no-name creeks and each of them present a different set of unique safety challenges. To determine which crossings received a warning system, Hays County looked at multiple facets to deem a crossing worthy. To determine which sites were to be monitored, the metrics examined were frequency of inundation, traffic counts, access issues, rescues, frequency of accidents, hydrologic/meteorological data gaps, current monitoring locations, input from the first responder community and predicted future growth. Most of this data was found in our *Hays County Low Water Crossing Urgency Rating* study. A complete list of all 22 sites selected for monitoring can be found in Appendix A.

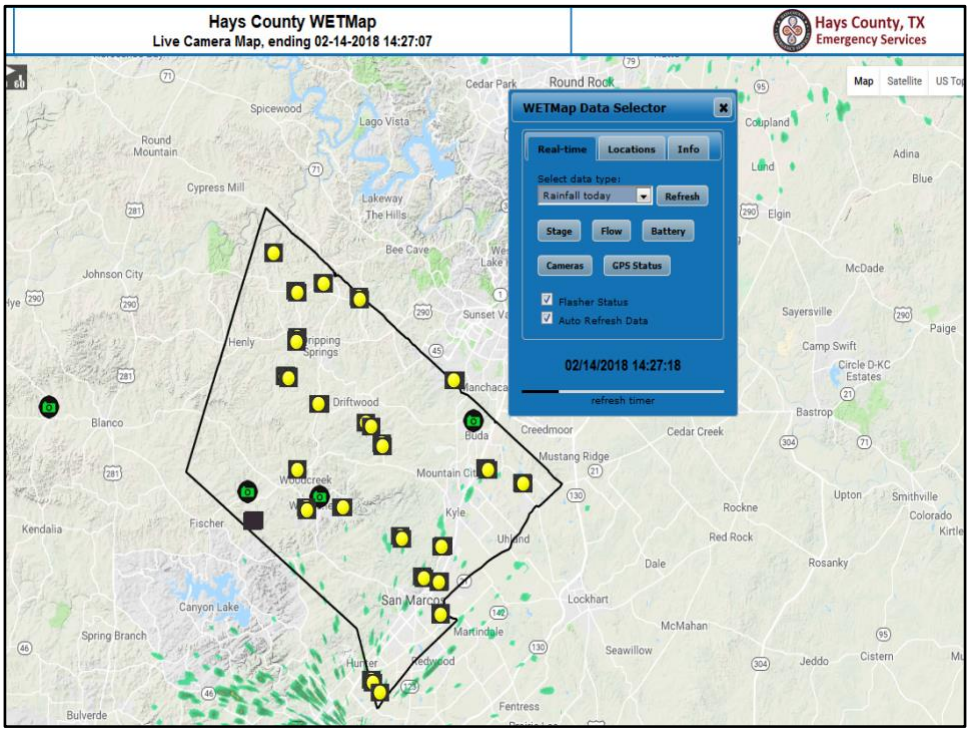


Figure 3. Hays County Low Water Crossing Monitors (with warning lights flashing)

To address the gap within the precipitation monitoring/warning infrastructure, collaboration with the National Weather Service (NWS) was necessary to assess where exactly the gaps were and identify locations that would benefit from improved precipitation monitoring. From the assessment, ten locations were identified for precipitation monitoring, which in turn assist the

NWS in making decisions on flood conditions. A list of all ten precipitation sites can be found in Appendix D.

In the 1980's five flood protection dams were installed in the Upper San Marcos River basin to help protect the City of San Marcos. There are three dams on Sink Creek and two dams on Purgatory Creek and all are now being monitored. Each site has a pressure transducer installed on the primary spillway, which allows Hays County officials to monitor the amount of water behind the dam. Specific elevations have been surveyed in and are now tied into the elevation of the transducer. These specific elevations allow for better interpretation of the hydrograph and aid in critical decision making.

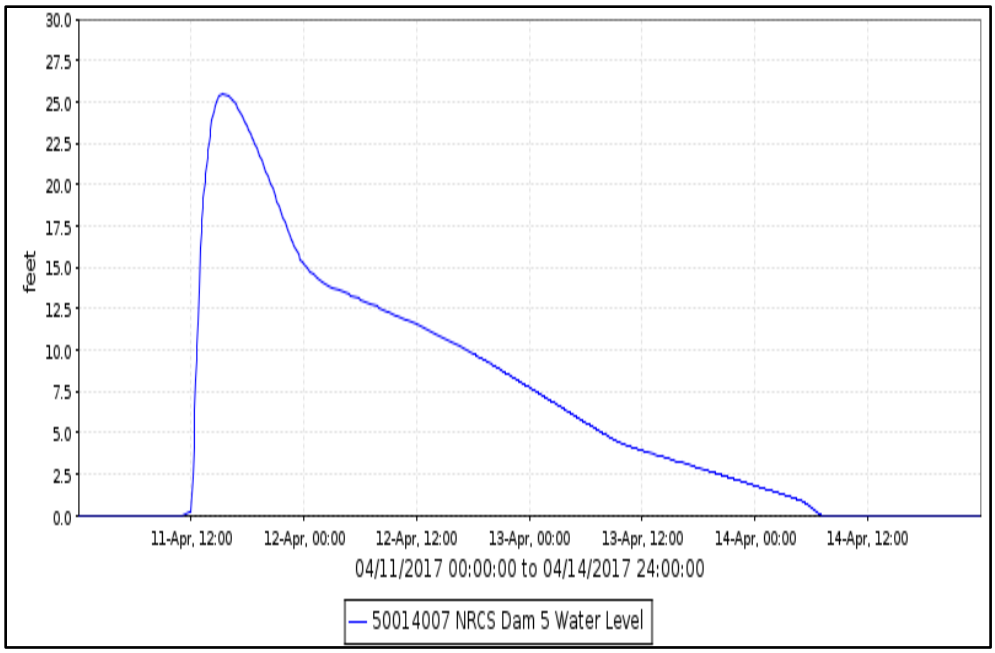


Figure 4. Site 5 Hydrograph

These dams prevent millions of dollars' worth of damage from happening each year and are important to the safety of the citizens below the dam. Shortly after installing the gages on the dams, a "rain bomb" occurred in San Marcos dropping around eight inches of rain in a little over two hours. The rain fell just upstream of Dam 5 causing a significant and dramatic rise. For the first time, a hydrograph was captured for Dam 5 which has been used frequently to show how important this new Flood Warning System is. The data in Figure 4 shows just how

quickly our systems can rise and just how important it is to monitor our streams and dams.

Equipment

After the floods in 2015, Hays County saw the benefit/necessity of having two-way communications with the field monitoring sites. There is a large tactical advantage of being able to interrogate the system as well as control flashers from an office computer or from a laptop in a patrol vehicle.

Hays County went out for bid, for a two-way flood warning system that implemented the Time Division Multiple Access (TDMA) ALERT2 protocols. This system allows Hays County to manage the transmission of data and communicate with the field sites by turning flashers off or on from the office.

Hays County's goal was to implement an entire system, which was non-proprietary, to allow for shorter down times, fewer equipment manufacturing shortages, and the ability to quickly train individuals to maintain/repair our system.

The industry standard protocol of SDI12 sensors, non-proprietary ALERT2 protocols, and standard traffic control equipment was implemented to reach the intended goal. Hays County chose not to implement automatic gates due to safety concerns, continual and costly maintenance and the liabilities associated with those types of systems.

There are many options for data transmission platforms and no one system is the perfect answer. Cellular data systems can bog down and become tied up during emergencies, Geostationary Operational Environmental Satellite (GOES) can take up-to an hour for data to transmit and receive from the field with no two-way communications which is a problem during dynamic flashflood events, Iridium which is private satellite company that provides high data transmit rate is expensive especially if you are transmitting large amounts of data, ALERT2 network

infrastructure is also expensive, upfront, but comes with myriad of positives over other data transmission platforms such as complete network control, two-way communications, open platform and high resolution data transmissions.

In conjunction with the Flood Warning System, Hays County installed permanent low water crossing gates. These gates are fixed on-site allowing Hays County personnel to quickly close down the roads. Hays County chose not to automate gate closures because of the upfront cost, long-term maintenance costs and malfunctions, which can cause costly repairs or indiscriminate closures. Originally, Hays County wanted to install a fixed gate at each crossing, but after further consideration, we felt that it was not warranted for some sites or site conditions disallowed for a permanent gate (e.g. spacing requirements, permissions etc.). Furthermore, we found that gates were more costly than what they were originally scoped out.

Within the original scope, we specked out four cameras to help monitor stream conditions. Unfortunately, we found the actual implementation of the cameras to be much more costly than originally anticipated. We opted to work with publicly available imagery through the USGS and partnering with Buda Fire Department to help bring mission-critical flood imagery to our Flood Warning system.

For the first round of installation we wanted to install 25 total flood warning gages at low water crossings throughout the County but ended up only installing 22. We needed to change the scope of work and allocate more funding to our radio infrastructure. We did this by adding two more base stations in key locations in Hays County. This decision was made impart by needing total redundancy of our system as well as ensuring that our network can see into every valley of our County. Furthermore, we decided to build out and harden the network on the front end to allow for the quick integration of new sites as this system continues to grow.

Web Based Flood Monitoring System

To further utilize the gages/monitoring systems being installed in the field, Hays County integrated the hydrologic data being collected with flood inundation data to create on-the-fly inundation maps. Hays County mapped out the 2, 5, 10, 25, 50, 100, 250, and 500 year flood frequency events and automated the inundation mapping of these frequencies based on the stage values being read in the field by our low water crossing sensors.

We also incorporated all of the 911 address points into the viewer to help monitor structural impacts as well as formulate evacuation plans. In addition to the automation of the inundation maps, there is the ability to turn on the next frequency event if the stream is still on the rise. Subsequently allowing for the mobilization of assets and personnel in a timelier manner based on the current trend.

In addition to the inundation maps that were created we took the opportunity to create discharge rating curves for 15 of our most critical sites. These sites were chosen based on their location within the County, availability of discharge related data in the basin, proximity to critical infrastructure and the necessity to watch flood events as they move downstream.

To further our capabilities and aid in understanding conditions, we decided to add the Hydrologic Rainfall Analysis Project (HRAP) grid system to the Flood Monitoring Site. This gives us the ability to examine, at near real time, precipitation accumulation conditions based on NWS radar. Table 1 helps illustrate the output file provided by the HRAP system.

Rainfall Accumulation by Hours

Hours	Amount
One	0.0
Two	0.0
Four	0.0
Eight	0.0
Twelve	0.1
Twenty-Four	0.7

Table 1. Hydrologic Rainfall Analysis Projection (HRAP)

Conclusion

Flood Early Warning systems are a necessity and an integral part of responding to and recovery from flood disasters, especially if your jurisdiction lies within the Flash Flood Alley of Texas. Unfortunately, due to how costly these systems are, it is out of reach for many jurisdictions that may need the situational awareness a flood warning system provides.

From a data standpoint, Hays County is now able to share a mass amount of hydrologic and meteorological data to many of its surrounding partners and partner agencies to help make informed decisions. In addition, the data can be shared internally so all departments within the County are provided the same operational picture during a flooding event. The data is now provided to our first responder community to help enhance their operations and for their pre-planning decisions. Engineers and owners of public infrastructure are also provided the hydrologic data to aid them in engineered designs and help understand inundation frequencies. The data is utilized as a supplement and helps ground truth radar data with the National Weather Service. Lastly, the data now helps groundwater and surface water authorities understand what is going on in their basins both hydrologically and meteorologically.

Hays County plans on adding more low water crossing systems each year as well as more precipitation monitors. The County is now collecting hydrologic data that has never been collected before taking us into new possibilities/capabilities. The data will be utilized to create flood models and inundation maps to help with pre-planning purposes as well as the creation of rating curves. These maps will also be available to our first responder organizations, Emergency Management, and Transportation departments. In addition, we have started implementing other natural hazard data, like Remote Automated Weather Stations (RAWS) into our system.

Lessons Learned

Implementing a Flood Warning System from scratch proved to be challenging. There were a lot of agreements that needed to be drawn up, there were several agencies involved in getting equipment installed and data transmitted properly, working with datasets and programs not typically seen by a relatively small jurisdiction and working within the confines of nature. Also, the cost of Flood Warning System is not to be underestimated. Equipment, specifically the telemetry equipment, is very expensive.

Mid-way through our project, Hurricane Harvey made landfall and truly tested our system. Overall the system worked great and was used for pre-planning purposes during Emergency Operations Center (EOC) operations as well as gathering in-situ intel. We did learn though that the placement of one of our rain gages was not conducive to the high winds that came with Harvey. The direction from which the wind was coming from as well as the wind speed against our tallest dam, caused the rain to go completely over our rain gage. This prevented us from measuring the correct amount of rainfall. The gage is currently in the process of being moved to a better location.

Acknowledgments

Thank you to our sponsors and those involved in such an impactful project:

Texas Water Development Board
National Weather Service
Lower Colorado River Authority
Texas Department of Transportation
Wimberley Fire ESD 4
North Hays Fire and Rescue ESD 1
Buda Fire ESD 2

Appendices

Appendix A
List of Monitored Sites

- BELL SPRINGS RD (CR 169) AT BARTON CREEK
- CHAPARRAL RD AT LITTLE BEAR CREEK
- CREEK RD (CR 190) & MT GAINER RD (CR 220) AT ONION CREEK
- CR 1492 AT BLANCO RIVER
- ELDER HILL RD (CR 170) AT SOUTH GATLIN CREEK
- FITZHUGH RD (CR 101) AT FITZHUGH CREEK
- HILLIARD RD (CR 222) AT SINK CREEK TRIBUTARY
- LIME KILN RD AT SINK CREEK
- JACOBS WELL RD (CR 220) AT CYPRESS CREEK
- LITTLE ARKANSAS RD (CR 174) AT BLANCO RIVER
- MT GAINOR RD (CR 220) AT SOUTH ONION CREEK
- OLD BASTROP HWY (CR 266) AT SAN MARCOS RIVER
- POST RD (CR 140) AT BLANCO RIVER
- RANCH ROAD 150 AT YORK CREEK
- RANCH ROAD 150 DOUBLE CROSSING AT ONION CREEK
- RAEFORD CROSSING AT PEDERNALES TRIBUTARY
- ROHDE RD (CR 126) AT BRUSHY CREEK
- TRAUTWEIN RD (CR 185) AT BARTON CREEK
- UHLAND RD (CR 161) AT YORK CREEK
- WAYSIDE DR (CR 179) AT BLANCO RIVER
- WINDY HILL RD (CR 131) AT ANDREWS BRANCH
- YORK CREEK RD (CR 262) AT YORK CREEK

Appendix B
Gated Sites

- GATLIN CREEK ROAD AT GATLIN CREEK
- SOUTH PLUM CREEK RD AT PLUM CREEK
- TRAUTWEIN RD (CR 185) AT BARTON CREEK
- VALLEY SPRINGS RD AT BLANCO RIVER

Appendix C
Base Stations

- BUDA FIRE STATION- STATION 3
- NORTH HAYS FIRE AND RESCUE- STATION 1
- HAYS COUNTY GOVERNMENT CENTER
- WIMBERLEY FIRE STATION- CENTRAL STATION

Appendix D
Precipitation Sites

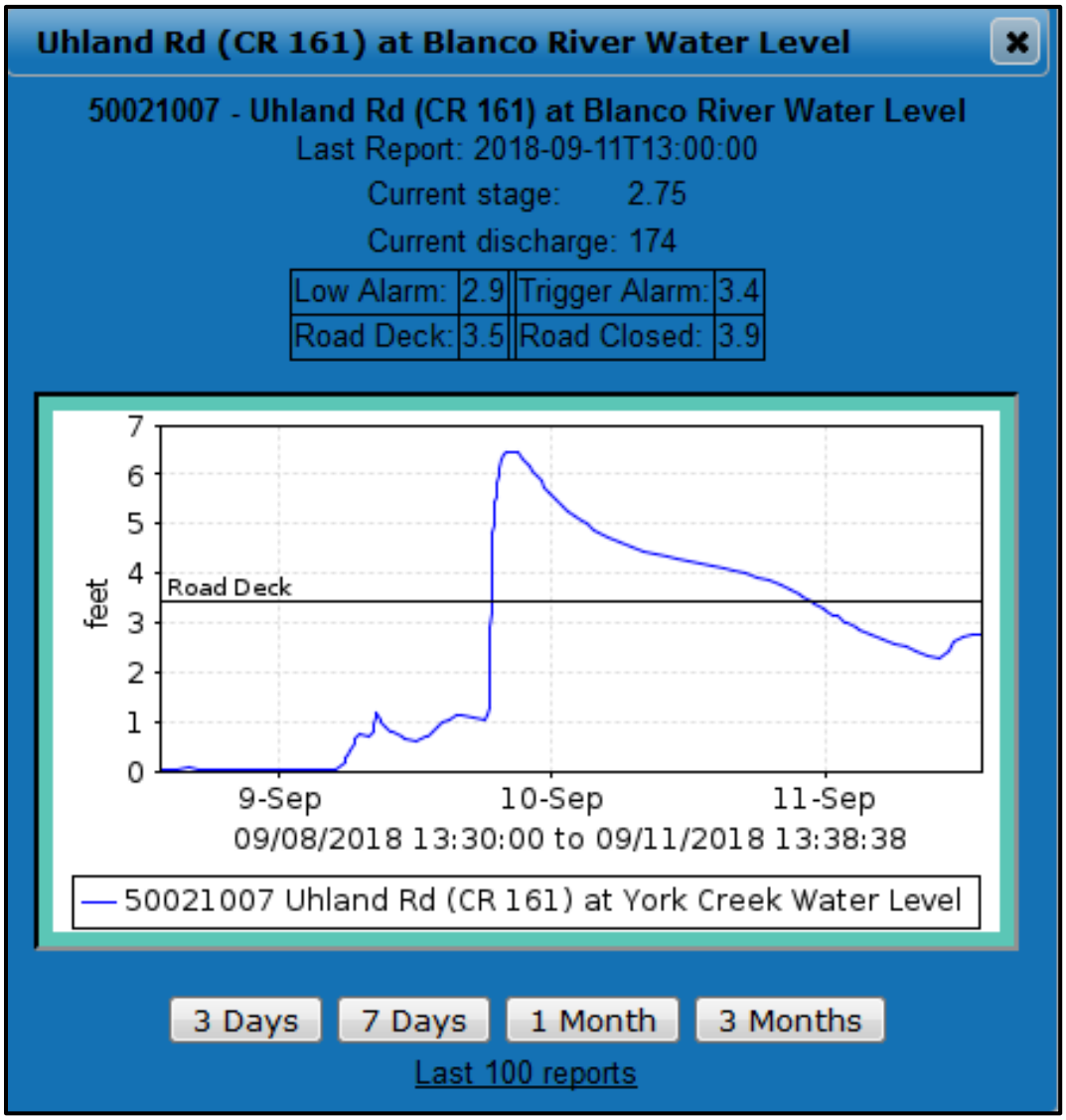
- CHAPARRAL RD AT LITTLE BEAR CREEK
- CREEK RD (CR 190) & MT GAINER RD (CR 220) AT ONION CREEK
- CR 1492 AT BLANCO RIVER
- HILLIARD RD (CR 222) AT SINK CREEK TRIBUTARY
- LITTLE ARKANSAS RD (CR 174) AT BLANCO RIVER
- NRCS DAM 4
- POST RD (CR 140) AT BLANCO RIVER
- ROHDE RD (CR 126) AT BRUSHY CREEK
- UHLAND RD (CR 161) AT YORK CREEK
- WAYSIDE DR (CR 179) AT BLANCO RIVER

Appendix E
All Stations

Site	Latitude	Longitude	Discharge	Stage	Camera	Reservoir	Precipitation	Base Station
YORK CREEK RD (CR 262) AT YORK CREEK	29°46'24.03"N	98° 0'17.89"W		x				
UHLAND RD (CR 161) AT YORK CREEK	29°53'42.89"N	97°53'57.96"W		x			x	
HILLIARD RD (CR 222) AT SINK CREEK TRIBUTARY	29°56'55.78"N	97°57'38.80"W	x	x			x	
LIME KILN RD AT SINK CREEK	29°53'59.55"N	97°55'34.88"W		x				
POST RD (CR 140) AT BLANCO RIVER	29°56'16.46"N	97°53'39.45"W		x			x	
WAYSIDE DR (CR 179) AT BLANCO RIVER	29°58'6.54"N	98°11'24.16"W	x	x			x	
CR 1492 AT BLANCO RIVER	29°59'2.28"N	98° 6'37.57"W	x	x			x	
LITTLE ARKANSAS RD (CR 174) AT BLANCO RIVER	29°59'4.40"N	98° 3'14.45"W	x	x			x	
JACOBS WELL RD (CR 220) AT CYPRESS CREEK	30° 1'47.90"N	98° 7'22.62"W	x	x				
ROHDE RD (CR 126) AT BRUSHY CREEK	30° 0'47.39"N	97°46'9.41"W		x			x	
WINDY HILL RD (CR 131) AT ANDREWS BRANCH	30° 1'55.40"N	97°49'43.27"W	x	x				
CHAPARRAL RD AT LITTLE BEAR CREEK	30° 8'16.37"N	97°52'40.99"W	x	x			x	
ELDER HILL RD (CR 170) AT SOUTH GATLIN CREEK	30° 6'35.96"N	98° 5'18.11"W	x	x				
MT GAINOR RD (CR 220) AT SOUTH ONION CREEK	30° 8'37.13"N	98° 8'23.09"W	x	x				
TRAUTWEIN RD (CR 185) AT BARTON CREEK	30°14'8.49"N	98° 1'29.17"W	x	x				
BELL SPRINGS RD (CR 169) AT BARTON CREEK	30°14'38.40"N	98° 7'22.15"W	x	x				
OLD BASTROP HWY (CR 266) AT SAN MARCOS RIVER	29°51'25.45"N	97°53'55.46"W	x	x				
RANCH ROAD 150 AT YORK CREEK	30° 3'33.69"N	97°59'23.85"W	x	x				
RAEFORD CROSSING AT PEDERNALES TRIBUTARY	30°17'30.36"N	98° 9'33.62"W		x				
FITZHUGH RD (CR 101) AT FITZHUGH CREEK	30°15'18.13"N	98° 4'54.79"W	x	x				
CREEK RD (CR 190) & MT GAINER RD (CR 220) AT ONION CREEK	30°11'11.45"N	98° 7'25.53"W	x	x			x	
RANCH ROAD 150 DOUBLE CROSSING AT ONION CREEK	30° 5'8.25"N	98° 0'51.10"W		x				
NRCS DAM 1	29°55'10.46"N	97°58'27.16"W				x		
NRCS DAM 2	29°55'57.71"N	97°57'43.23"W				x		
NRCS DAM 3	29°54'24.53"N	97°56'43.32"W				x		
NRCS DAM 4	29°53'5.93"N	98° 1'54.96"W				x	x	
NRCS DAM 5	29°52'7.87"N	97°58'9.68"W				x		
HAYS COUNTY GOVERNMENT CENTER	29°51'54.8"N	97°57'14.7"W						x
WIMBERLY FIRE- CENTRAL STATION	30°00'06.7"N	98°06'22.2"W						x
BUDA FIRE- STATION 3	30°05'48.8"N	97°52'44.9"W						x
NORTH HAYS FIRE AND RESCUE- STATION 1	30°11'45.8"N	98°05'49.3"W						x

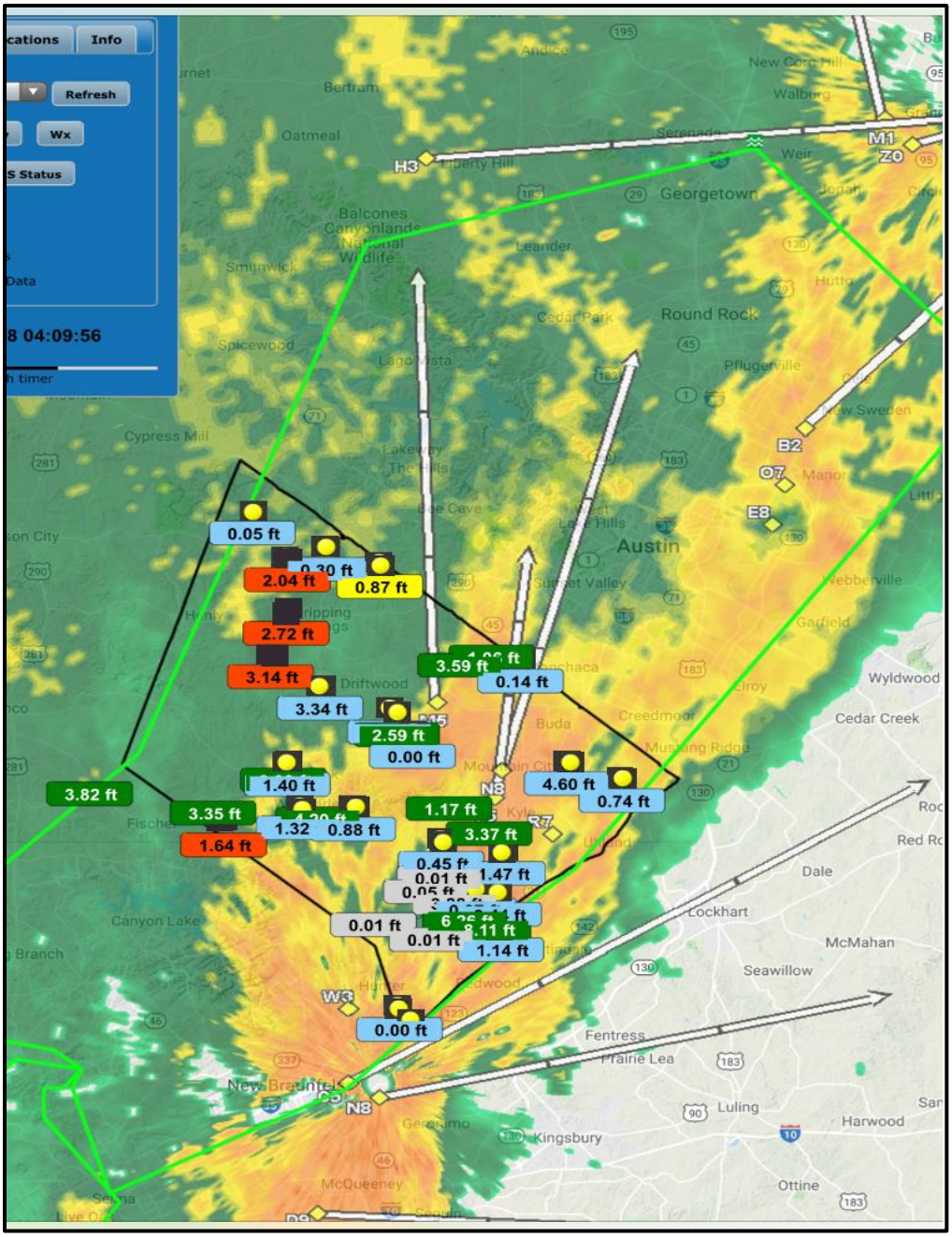
Appendix F

Road Deck Notation During a Rise



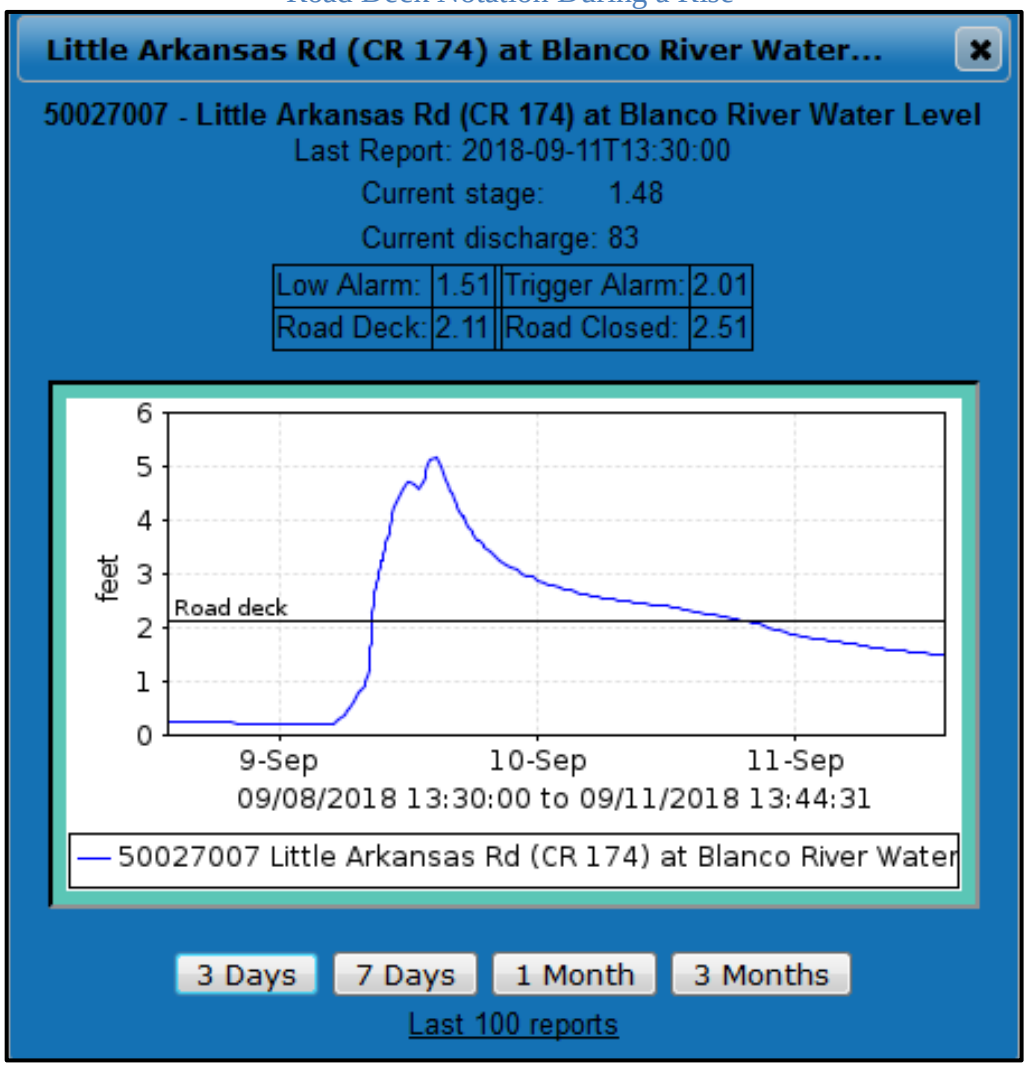
Appendix G

Flood Warning System During and Event



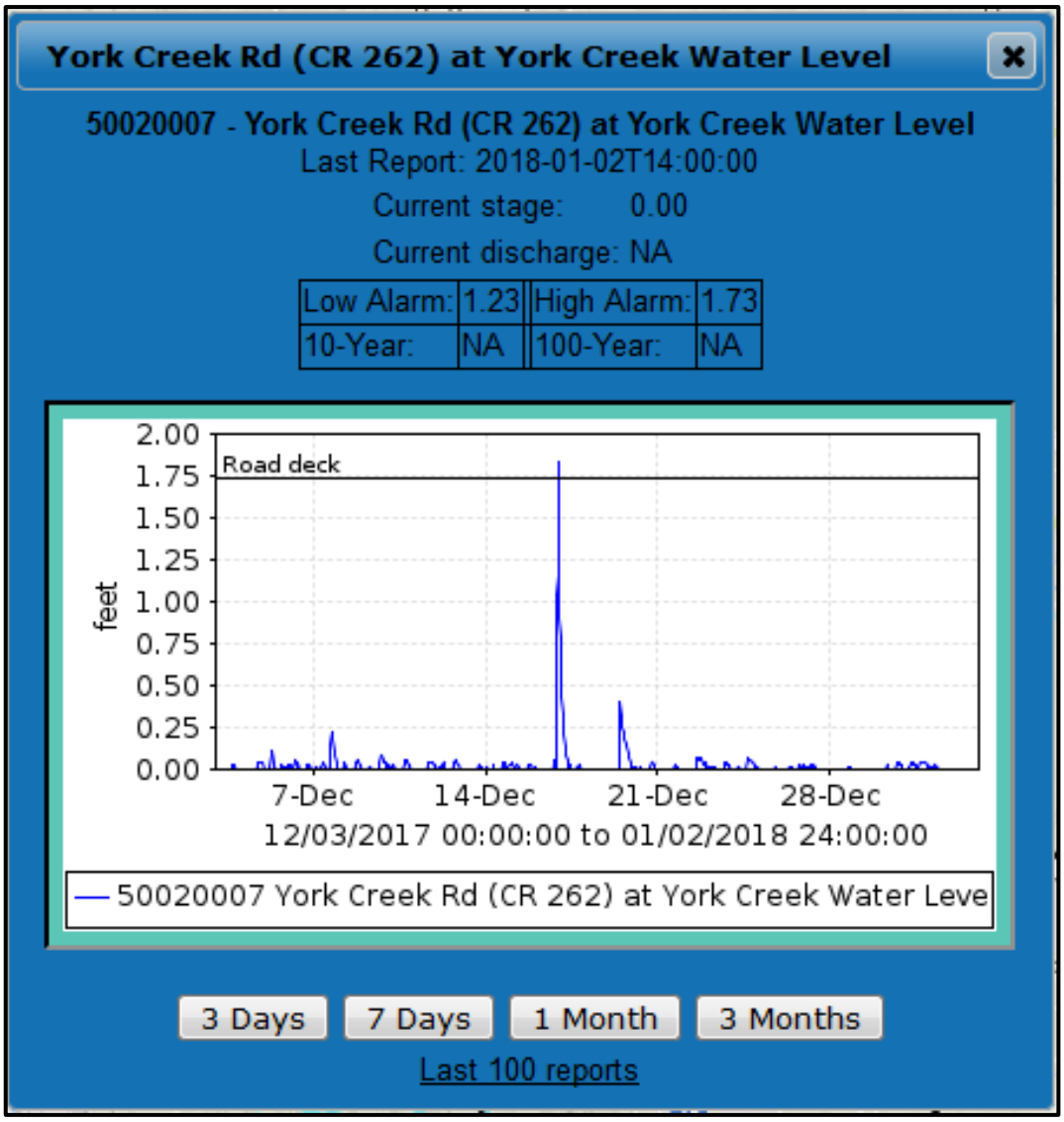
Appendix H

Road Deck Notation During a Rise



Appendix I

Road Deck Notation During a Rise



Appendix J
Site Installation Drawings

Water & Earth TECHNOLOGIES

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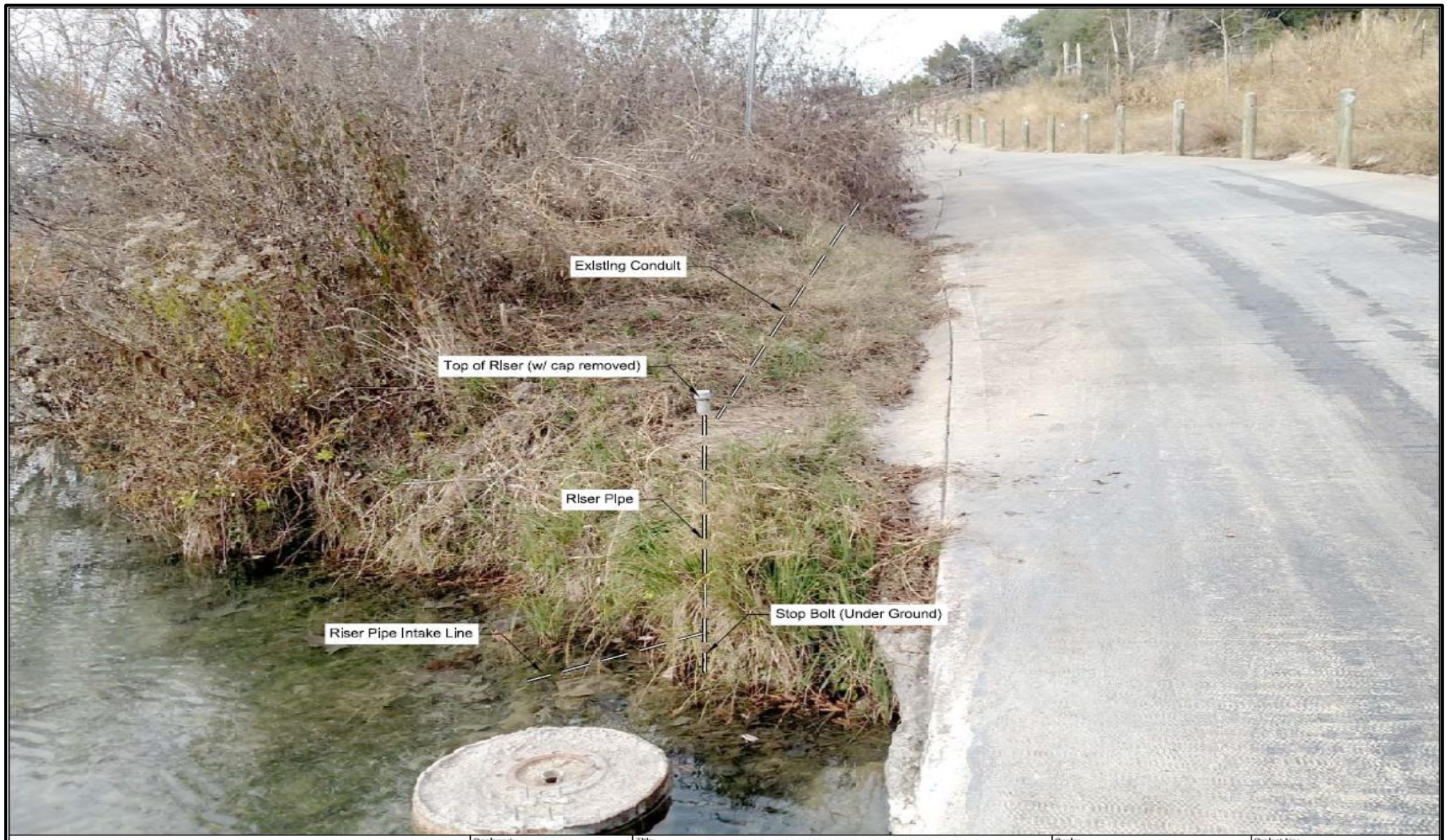

Water & Earth TECHNOLOGIES

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Water & Earth TECHNOLOGIES

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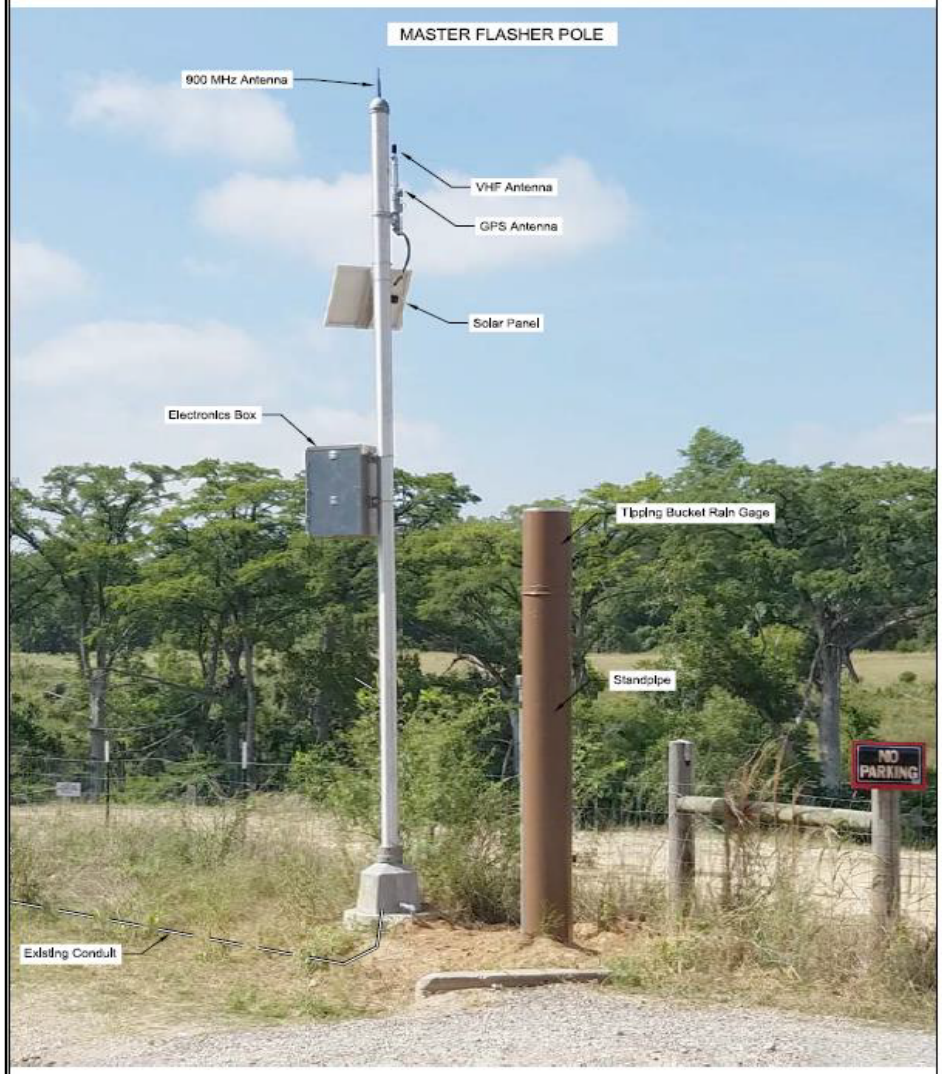

Water & Earth TECHNOLOGIES

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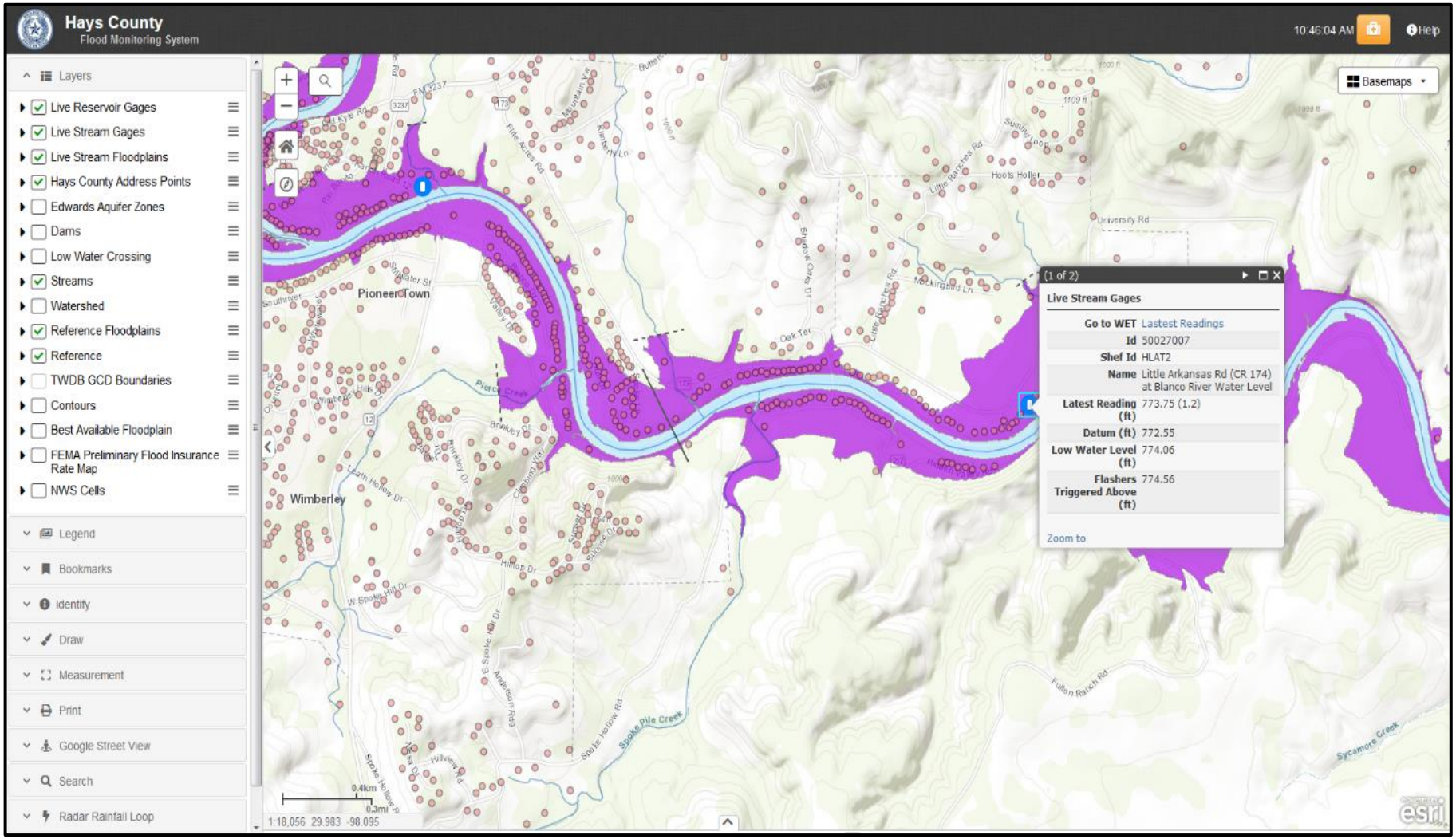
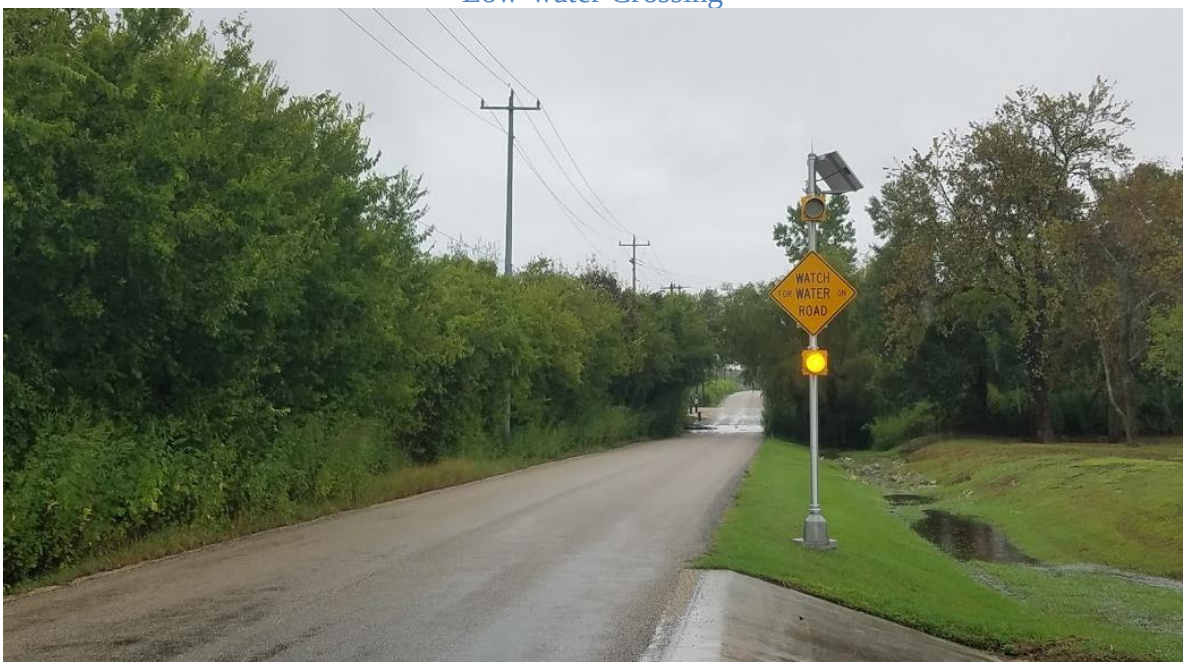
Appendix K
Inundation Map



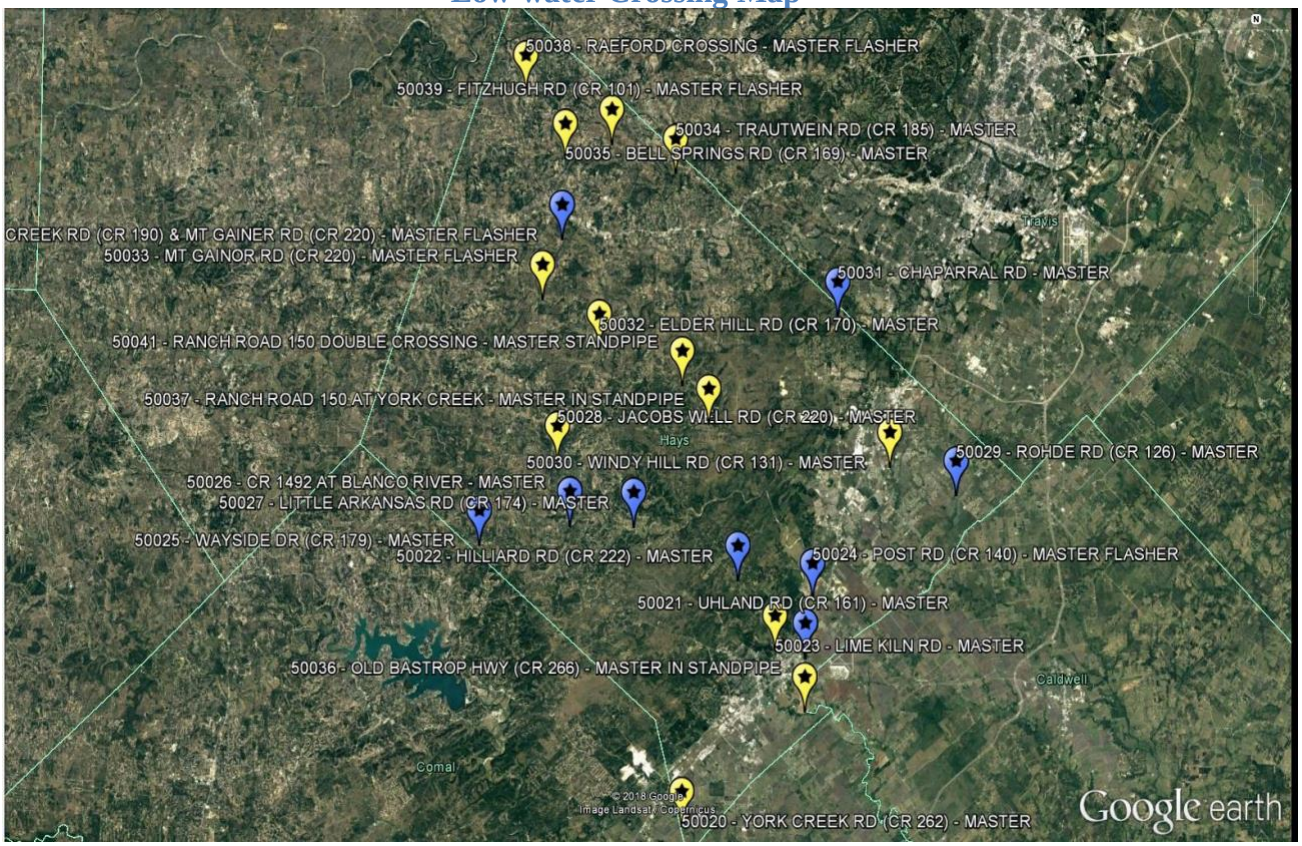
Appendix L
Dam Gauge

Appendix M
Rain Gauge

Appendix N
Low-water Crossing



Appendix O
Low-water Crossing Map



Appendix P
Texas Water Development Board Comments to Draft Report

Attachment 1

Increasing the Safety of Hays County Citizens and First Responders through Hydrologic Data and Low Water Crossing Monitoring
Hays County
Contract #1600012045
Texas Water Development Board Comments to Draft Report

REQUIRED CHANGES

General Draft Report Comments:

In general, the study follows standard methodologies and practice. Mitigation alternatives identified by the study may be eligible for funding under the Texas Water Development Board's financial assistance programs. Application requirements and eligibility criteria are identified by Texas Water Development Board rules specified in Section 363 of the Texas Administrative Code (TAC). The report would be appropriate for use in support of an application to the Board for financing the proposed improvements. All additional information required by Board rules, 31 TAC 363.401-404, as well as necessary information to make legal findings as required by Texas Water Code Chapter 17.771-776, would be required at the time of loan application.

Please conduct a thorough final edit of the document for grammar, spelling, typographical errors, and inconsistent usage of acronyms, and abbreviations. Please spell out all acronyms, with the acronym in parentheses, the first time they are used. Please include a list of acronyms used in the report after the Table of Contents.

Specific Draft Report Comments:

1. The scope of work indicates that the project will include; the installation of two (2) base stations, twenty-five (25) low water crossings which record stream discharge and stage values, ten (10) of the twenty-five low water crossing locations will house
precipitation gauges, and four (4) of the twenty-five low water crossing locations will include a camera for near real-time visual feed of current conditions, as well as,
five (5) reservoir monitoring gauges that will monitor reservoir stage above mean

sea level. Please ensure that the report includes a discussion of all these items or a discussion on why the decision to not perform the work was made. (see items below: No. 2 under Specific Draft Report Comments and Nos. 1, 2, 3, and 4 under Exhibits and Tables Comments for example of areas where updates are needed)

2. Page 6 (and Appendix A) references 22 monitored sites while the scope of work indicates that 25 sites would be monitored. Please include a discussion on the sites that were not included for monitoring.
3. Page 10, Lessons Learned section, provides a brief discussion; however, does not indicate the lessons learned. Please, provide a discussion of the lessons that were learned during this project or remove section.

Exhibits and Tables Comments:

1. The report includes a map, a list of the monitoring sites, and a list of the gated sites; however, these are not very specific. Please, include both a map(s) and a list(s) of the sites which indicates the common name (YORK CREEK RD [CR 262] AT YORK CREEK), latitude and longitude of the various sites (from google maps would be ok), and the functionality of equipment found at each site (such as base stations, stream discharge and stage value data gathering, precipitation gages, cameras, and reservoir monitoring gages). (These reports will often include an image of the site so that future users of this document will recognize the equipment being referenced. It looks like the consultant may have provided photos which could be attached).
2. Appendix B includes a list of four gated site installations while the scope of work indicates that 25 flood gates would be installed at low water crossings. Please, include a discussion on why the decision was made to only install four gated sites.
3. Page 6 states that ten locations were identified for precipitation monitoring. Please provide a list, maps, etc., that may be helpful of the ten locations that would benefit from improved precipitation monitoring (please, see No. 1 under Specific Draft Report Comments).
4. Page 6 discusses the dam sites that are being monitored. Please include, in the discussion, the type of monitoring and also provide any maps, lists, etc. that may be helpful (please, see No. 1 under Specific Draft Report Comments).
5. Page 8, Table 1 – This table needs to be cleaned up. Please remove all unnecessary icons, as well as “zoom to” and “(4 of 4)”. Lastly, please spell out the acronym used to label the table.
6. Appendix F – Arrows and labeling, indicating locations of items, should to be more visible, please, update.