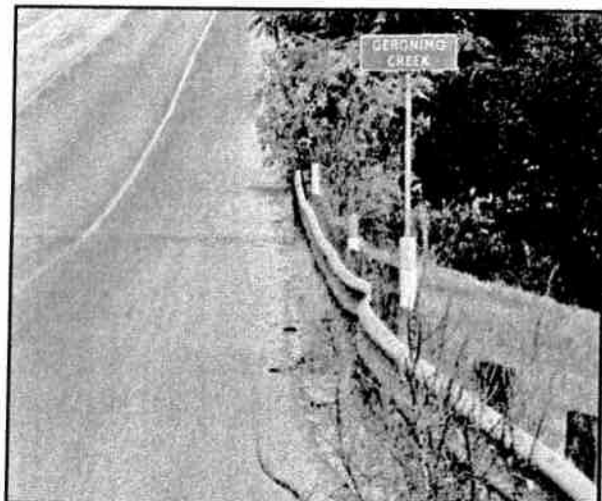
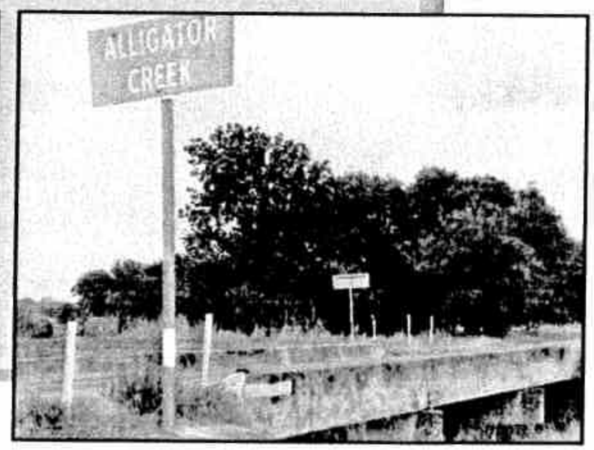
M&S ENGINEERING, LLC
Engineers, Planners, Surveyors

# FINAL
# Geronimo Creek
# Flood Protection Plan




Guadalupe County, Texas
June 2011



0904830951_Final Report

M&S ENGINEERING, LLC
Engineers, Planners, Surveyors

# FINAL
# Geronimo Creek
# Flood Protection Plan



Guadalupe County, Texas
June 2011

# FINAL
# Geronimo Creek
# Flood Protection Plan

Prepared for:
Guadalupe County
2605 N. Guadalupe St.
Seguin, Texas

June 2011

M&S Engineering, LLC Project No. 9GUADCO001

**_Main Office:_**
Post Office Box 970
6477 FM 311
Spring Branch, Texas 78070
Telephone: (830) 228-5446
Facsimile: (830) 885-2170
*Web:* www.msengr.com

**_Branch Office:_**
Post Office Box 391
McQueeney, Texas 78123

6/29/11

Prepared by:
Lance Klein, P.E., P.H., CFM,
Jerod Mott, E.I.T,
Stephen Jackson
M&S Engineering, L.L.C.
Texas Registered Engineering Firm F-1394

# TABLE OF CONTENTS

## LIST OF APPENDICIES



## LIST OF FIGURES



## LIST OF TABLES

# EXECUTIVE SUMMARY

This document is a Flood Protection Plan for Geronimo Creek, including its major tributary Alligator Creek, located in Comal and Guadalupe Counties, Texas. The combined watershed includes portions of Comal County, the City of New Braunfels, Guadalupe County, and the City of Seguin. Geronimo Creek ultimately confluences with the Guadalupe River.

Guadalupe County officials initiated an application to the Texas Water Development Board (TWDB) for funding assistance through the Flood Protection Planning Program in January of 2009. The application for funding was approved and contracts executed on August 18, 2009. In addition to Guadalupe County the following local governments and agencies supported the efforts of the study: Comal County, City of New Braunfels, City of Seguin, and Guadalupe-Blanco River Authority (GBRA). An Oversight Committee was created, made up of representatives from each of the local participants, the TWDB, and M&S Engineering (M&S) staff.

The primary goal of this study is to identify potential methods to reduce flooding in the Geronimo Creek watershed. There are two objectives identified in order to achieve this goal. One objective is to create detailed hydrologic and hydraulic models that evaluate existing watershed conditions in order to identify the impacts due to development since the Effective FEMA Flood Insurance Study that was performed in 1976. The second objective is using the hydrologic and hydraulic data to evaluate structural and non-structural mitigation alternatives and determine if these alternatives are cost beneficial options for reducing the risk and frequency of flooding.

The Oversight Committee charged M&S to evaluate seven flood mitigation alternatives. Four of the alternatives were structural measures that were evaluated using standard engineering practices of hydrologic and hydraulic modeling, construction cost analysis, and cost/benefit analysis based on impacts. These structural projects included: channel modifications, brush removal, bridge and low water crossing improvements, and regional detention ponds. The remaining non-structural options were regional detention regulations, and flood early warning systems. These non-structural solutions were difficult to calculate inherit benefits, construction costs, or implementation costs. Buyouts for repetitive loss structures in one area of the watershed were evaluated.

Channel modifications, brush clearing, and stream crossing improvements were found to have negligible impacts on the water surface elevations of the floodplain. Although making improvements to roads and bridges could reduce the risk of loss of life for motorists, it had a limited impact on flooding and proved to be non-beneficial based on construction cost. The investigation of using detention ponds to reduce flooding resulted in beneficial impacts to the floodplain. Due to characteristics of the watershed, large detention ponds will be required to achieve the desired level of flood reductions.

In addition to the construction of detention ponds to mitigate current flooding; a floodplain management and regulatory approach shows promise in reducing future damages and loss of life.

**ACKNOWLEDGEMENTS**

Numerous people contributed to the successful completion of this study. M&S Engineering, LLC wishes to acknowledge the following individuals as key contributors and supporters of the Geronimo Creek Flood Protection Plan.

**M&S Engineering, LLC, project staff**

Keith C. Strimple, P.E., CFM, Principle in Charge
Lance Klein, P.E., P.H., CFM, Project Manager
Jerod Mott, E.I.T., Engineering Technician
Stephen Jackson, Hydrologist
Leona Laijas, Administrative Support

**Representatives of Guadalupe County, local sponsor**

Hon. Mike Wiggins, Judge
Roger Baenziger, Commissioner
Kyle Kutscher, Commissioner
Jim Wolverton, Commissioner
Judy Cope, Commissioner
Larry Timmerman, CFM, Environmental Health Director, Road Administrator
Jimmy Harless, CFM, Floodplain Administrator

**Texas Water Development Board, state sponsor**

Gilbert Ward, P.E., CFM, Planning Division
Kathy Hopkins, CFM, Planning Division
Manuel Razo, CFM, Texas Natural Resources Information System

**Additional members of Oversight Committee**

Joe Ramos, P.E., City of Seguin
Donald Smith, City of Seguin
Steve Ramsey, P.E., City of New Braunfels
Clint Humes, E.I.T., Comal County
Debbie Magin, Guadalupe-Blanco River Authority

**Subconsultants**

David Ellis, R.P.L.S., Sherwood Surveying
Rico Laijas, Sherwood Surveying
Roger Stack, Stewart Geo Technologies
Chad Martin, PWS, CWB, Malcolm Pirnie, Inc.

A special thank you goes to the Navarro Independent School District for use of their elementary and junior high school cafeterias for public meetings.

# 1.0 INTRODUCTION

The Geronimo Creek Flood Protection Plan is a flood study funded by the TWDB and Guadalupe County, with participation from the City of New Braunfels, Comal County, the City of Seguin, and the GBRA.

Geronimo Creek and Alligator Creek, one of the major tributaries of Geronimo Creek, have experienced severe flooding in recent years. The severity and the frequency of these flooding events have increased rapidly as the watershed has experienced substantial development. Obviously, the increase in development increases the amount of impervious cover in the watershed, thereby increasing the severity and frequency of the flood events. The enlarged amount of impervious cover increases peak runoff and increases flooding of structures currently in the floodplain and also increases the risk of additional structures being damaged by floodwaters. With the increase of development comes increasing numbers of travelers who are using roads and subsequently, low water crossings that place travelers in the path of floodwaters.

In November 2007, the 100-year floodplain maps for Guadalupe County were revised indicating an approximated 525 structures located within the mapped flood limits. Life-threatening flooding has occurred nearly every year since October 1998 (March 2007, June 2004, July 2002, November 2001, August 2001, and of course the record-setting flood of October 1998). Prior to October 1998, major flooding was documented in May 1972 and September 1952. It is presumed that the increase in flooding since 1998 is partially a function of the development within the watershed of the Geronimo Creek as well as other upstream developments.

It is apparent that flooding within the Geronimo Creek watershed has increased and is expected to further increase, placing the health, safety, and welfare of the citizens of the watershed and those who travel through it at additional risk. It is even more apparent that flood protection and drainage infrastructure must be reviewed and studied to decrease the risk of placing the general public at undue risk.

## 1.1 Study Area

The Geronimo and Alligator Creeks are located in South Central Texas with the majority of the watershed located in Guadalupe County (See Figure 1-1). The headwaters of Alligator Creek are in Comal County. From there, Alligator Creek flows through New Braunfels, into Guadalupe County and intersects Geronimo Creek 1.5 miles west of the Community of Geronimo which is located on Hwy 123, north of the City of Seguin, in Guadalupe County.

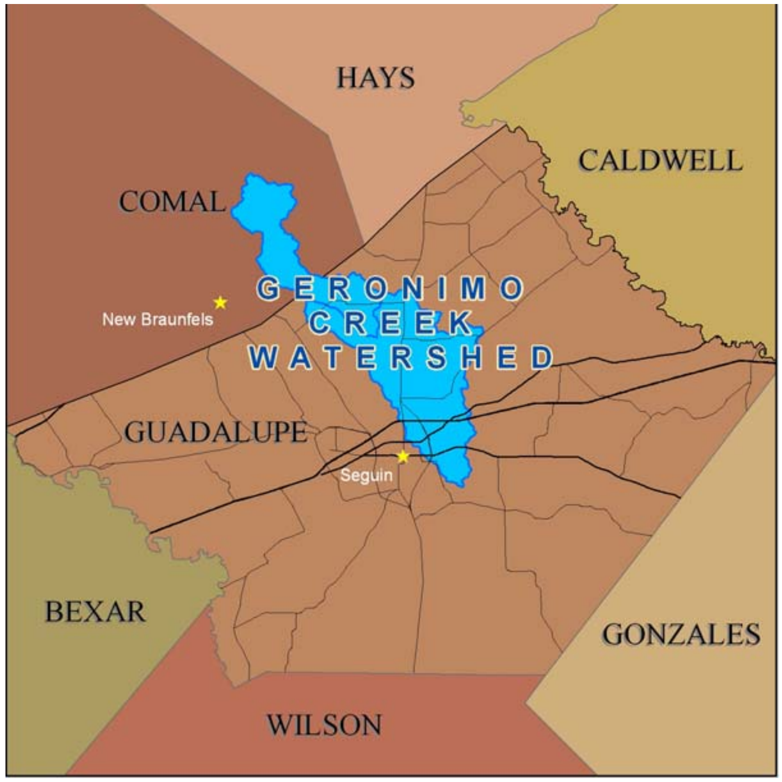


Figure 1-1: Study Area

Geronimo Creek's headwaters are located south of the New Braunfels Municipal Airport located in Guadalupe County. From the airport, Geronimo Creek flows approximately 3.5 miles to the southeast where it intersects Alligator Creek. Downstream from the confluence of the Geronimo and Alligator Creeks, the stream holds the name "Geronimo Creek" and travels approximately 13 miles, through the City of Seguin, and ultimately intersects the Guadalupe River.

The Geronimo Creek watershed (including Alligator Creek and all associated tributaries) has a total watershed of 68.65 square miles. The upper and lower sections of the watershed are urbanized while the stream segment in between contains rural subdivisions and small communities. With increased industrial and commercial development realized in Guadalupe County and the construction of SH-130, the middle stream segment will experience further, increased development.

Elevations in the watershed range from a high of 1020 feet at the upper reaches of the headwaters to a low of approximately 450 feet at the confluence with the Guadalupe River. The watershed, from the headwaters of Alligator Creek to the confluence of the Guadalupe River, is approximately 22 miles long and at the widest is approximately 7 miles wide.

The entire watershed was studied because Guadalupe County realized the need to evaluate the watershed as a complete, all-encompassing, system. Additionally, it is essential to incorporate all of the entities to provide a cumulative approach to flood protection planning.

## 1.2 Scope of Services

Because there were numerous sponsors and participants who were varied in need and purpose, communication has been vital throughout the study, and especially critical in the initial phases. Public input as well as input from the sponsors provided direction and insight from all the parties affected and was needed for the project to be a watershed-wide success. The economies, demographics, and "personalities" throughout the expansive watershed are varied and needed to be addressed.

The fundamental objective of this proposed flood protection planning was to thoroughly integrate all of the various needs of affected persons and sponsors into one effort, using the latest hydrologic studies made available to achieve a broad and comprehensive flood reduction plan for the entire watershed. Generally, current studies were to be updated to reflect current and potential future conditions, field data would be obtained as necessary, existing structures verified, data on new structures gathered, environmental considerations associated with proposed solutions evaluated, and benefit-cost analyses conducted.

Guadalupe County underwent FEMA Flood Insurance Rate Map (FIRM) revisions in November of 2007. Initially it was understood that the revised Effective FEMA hydrologic and hydraulic studies would be used as a baseline and built upon, adding more detail based on current development and topography. Upon obtaining FEMA backup data it was discovered that the Effective Flood Insurance Study (FIS) for the study area was outdated and incomplete. Therefore the scope of work to complete the study changed drastically.

A detailed break down of the project tasks as outlined in the Grant Application and the TWDB contract:

*a.* *Project Start and Baseline Information* - The project will begin with "communication" the most critical component, in the form of a kick off meeting with all of the sponsors and other political subdivisions that may have an interest in the planning effort. This meeting will set goals, project scope, project schedules, assign responsibilities, identify problem areas, anticipate project achievements, and initiate the compilation of all data that may be available. Geographic Information Systems (GIS) data will be obtained from Comal County, Guadalupe County, and the City of New Braunfels. Current (FIS) and United States Army Corps of Engineers (USACE) hydrologic and hydraulic models will be obtained as well as any past studies, possible FEMA Letter of Map Revisions (LOMRs), geotechnical information, topography, and any other related and necessary information. Once project goals, scope, and objectives are confirmed and agreed upon through the meeting with the sponsors, a public meeting will be held in a location central to the watershed – potentially in the community of Geronimo. This meeting will be to solicit the general public's input, concerns, perceived trouble areas, and "on the ground" information as well as communicate to the public the objective of the study. National Flood Insurance Program (NFIP) policy holders who have experienced a flood event will be determined and identified in this task. The final product of this task will be a planning area base map and a clear understanding of goals, responsibilities, project schedules, and scope.

*b.* *Environmental Considerations* – Part of the watershed (Alligator Creek segment) falls within the Balcones Escarpment. Accordingly, environmental issues related to the Edwards Aquifer Recharge Zone must be taken into account when considering any possible solution for flood protection. In addition to possible concerns related to the Recharge Zone, other potential critical environmental features must be identified and considered. Although a detailed survey will not be conducted, endangered species, wetlands, and other potential environmental issues will be reviewed and identified through available information by a subcontractor (Malcolm Pirnie) who will also address any storm water quality concerns. Additionally, all work related to environmental effort/task will be coordinated with the water quality modeling program that the GBRA is currently developing but, no funding from this grant will be used to support that effort.

*c.* *Field Data Collection* – From information gathered in the Project Start task and through the review of data acquired from the previously conducted hydrologic studies, information or data/survey “gaps” will be identified. It is anticipated that approximately 2,000 feet of stream channel may require additional cross-sectioning, and that approximately 20 days of survey crew will be required to verify stream crossing data and obtain data from crossings where no data is available.

*d.* *Hydrologic Considerations* – Making use of the model used to develop the FIRMs revised in November 2007 as well as other data obtained in the Project Start task, an updated hydrologic model will be developed that integrates all of the data made available using USACE Hydrologic Engineering Centers – Hydrologic Modeling System (HEC-HMS). Utilizing existing data will greatly reduce time and effort needed as it relates to having to develop times of concentration, curve numbers, etc. for the existing model. Soils data, rainfall distributions, and land use estimates provided and used in the existing model will be evaluated and modified as needed to develop existing hydrologic data and future hydrologic data. Separate HEC-HMS models will be developed, including calibrating/verifying the existing model, updating the model to current conditions, and modeling future land use conditions. Each model run will develop 2-year, 10-year, 25-year, and 100-year peak flow rates for use in the hydraulic model. In summary, this effort will, ultimately provide storm water flows at 4 frequencies (2, 10, 25, and 100-year) for the model as it currently exists (as of November 2007), existing (current time), and for the ultimate development of the watershed.

*e.* *Hydraulic Considerations* – Utilizing the data from the model previously described, other data obtained in the Project Start task, field survey data, topographic and GIS data obtained from Guadalupe County, information gathered from sponsors, design plans and the most up to date topographic data available from other sources, the USACE Hydrologic Engineering Centers – River Analysis System (HEC-RAS) model runs will be verified for its current state (November 2007). Upon verification and calibration of the model as developed and approved in November 2007, current or existing conditions (present day) will be run in the model as well as projected future land conditions. Flood profiles will be developed for the existing conditions (present day) and the expected, ultimate development, future land use conditions for the 2-year, 10-year, 25-year, and 100-year watershed conditions. The final product of this task will be flood profiles and floodplain delineations for both the existing and future conditions.

*f.* *Assessment of Potential Flood Protection Measures* – Using the data from the aforementioned analyses (2-year, 10-year, 25-year, and 100-year peak flows for both existing/present day and future conditions), an acceptable level of flood protection for each problem area identified. Hydrologic and hydraulic analyses will be performed for each scenario identified at the present day and future conditions for each of the flood frequencies to aid in determining the amount of protection provided. The flood protection measures may include structural and/or non-structural improvements including, but not limited to: channel improvements, culvert upgrades, low water crossing upgrades, buy-outs, flood-proofing, in-channel detention, and off-channel detention. Non structural measures may include items such as regional regulations and policies, land planning, land use restrictions, etc. The potential flood protection measures will be communicated to the sponsors of the study through a detailed report showing the results of the analysis. Their input and consideration will be integrated into the detailed report and then communicated to the general public through a second public meeting. The public meeting will be to present the findings to date and to describe how benefit-cost analyses will be used, in addition to input from the sponsors and the public, in narrowing the selection of protective measures to 5 scenarios.

*g.* *Benefit-Cost Analyses*- Each alternative will be quantified in terms of the benefit ("tangible" and "intangible") the protection measure provides. Although "tangible" benefits are more easily quantified, "intangible" benefits such as reducing bank erosion, reducing subsidence, reducing disruption to infrastructure, reducing disruption to economies, etc. are difficult to quantify, but will be applied in a subjective manner to the proposed solutions. These benefits will be compared to the cost associated with constructing the protective measure including, but not limited to: capital costs, financing costs, life cycle, right of way requirements, maintenance costs, etc. In the event the benefit-cost ratio appears to be inappropriately skewed, the FEMA benefit-cost analysis software will be utilized as a comparison. Capital costs will be based upon current construction unit pricing, consultation with contractors, GIS data made available by the sponsors, and rough, preliminary schematics of the suggested protection measure. Using the benefit-cost ratios as a beginning measure for prioritizing, public health and welfare benefits associated with the scenario will be evaluated to provide additional and more critical prioritizing measures. The final product of this task will be a report showing all of the studied protection measures including benefit-cost analyses, "intangible" benefits and costs, costs of improvements, discussion of public health and welfare benefits, and prioritization of the proposed solutions. Projects that have the higher benefit-cost ratios will be ranked with the highest priority with subject to consideration to the "intangible" considerations. This task will be presented in a third public meeting upon approval of Guadalupe County and the sponsors.

*h.* *Financing/Implementation Phases* – Based upon the input from the sponsors and the public on the benefit-cost analysis/study, the effort of defining financing alternatives will be explored. Potential funding sources include, but are not limited to: impact fees, development fees, utility fees, grants, taxes, capital budgeting. The sponsors' individual capital improvement plan(s) and budgeting will be considered and coordinated with others to obtain the broad, watershed-wide, solution(s) that is inherent in this proposed study. Recommendations will be provided for implementing and financing the suggested flood protection measures.

*i.* *<u>Deliverables</u>* – Upon the completion of the tasks listed, including the deliverables indicated in each task, a final document will be developed. This document will be the accumulation of all of the efforts associated with the study and will be presented to the public in a final, fourth public meeting. The final report, which will include, maps, technical analyses, exhibits, supporting documentation, and implementation/ financial considerations, will be entitled, "Flood Protection Plan for Geronimo and Alligator Creeks' Watersheds". The report will be presented to the Texas Water Development Board following the completion of the final meeting and approval of Guadalupe County.

## 1.3 Oversight Committee

As previously mentioned, an Oversight Committee was formed to provide assistance, guidance, and general support to the study effort. The committee met six times during the course of the project and was a large contributing factor to the effectiveness and completion of the study. In addition to the Oversight Committee meetings, members also attended the three public meetings that were held throughout the project period. They provided invaluable input and support while addressing questions and comments from residents and property owners.

## 1.4 Public Meetings

Three public meetings were held at different key phases of the study. Each meeting had a formal presentation, question and comment time, and a workshop session in which the public provided input and were able to speak with M&S staff and Oversight Committee members. Public notice for each meeting included announcements in local papers, radio stations, television stations, and Guadalupe County Commissioners Court. In addition, written invitations were sent to the residents and property owners in the study area.

The first meeting was held on November 4, 2009 at the Navarro Elementary School Cafeteria. Participating agencies, consultants, and local governments were introduced to the attendees. An update was given by GBRA and AgriLife Extension on the efforts associated with the Geronimo and Alligator Creeks Watershed Protection Plan, in which water quality of the watershed is being evaluated. M&S presented a detailed description of history, purpose, and goals for the study. During the workshop session attendees filled out questionnaires regarding their personal experiences with flooding and located problem areas on watershed maps. Valuable information was obtained from the public and was used for hydraulic model validation, prioritizing flood prone areas, and establishing initial locations of potential detention structures.

The second public meeting was held on June 16, 2010 at the Navarro Middle School Cafeteria. Participating agencies, consultants, and local governments were introduced to the attendees. An update was given by GBRA on the status of the Geronimo and Alligator Creeks Watershed Protection Plan. M&S presented a brief overview of the purpose of the study and updated attendees on the work completed to date. M&S presented an aerial flyover displaying a graphical comparison of the Effective FEMA 1% annual floodplain and the newly calculated 1% annual floodplain. The flyover began at the headwaters of the Alligator Creek and moved downstream through Geronimo Creek to the confluence with the Guadalupe River. During the workshop sessions attendees viewed more detailed maps of the floodplain comparison, asked questions, and expressed concerns to M&S staff and Oversight Committee members.

The final public meeting was held on August 18, 2010 at the Navarro Middle School Cafeteria. Participating agencies, consultants, and local governments were introduced to the attendees. An update was given by GBRA on the status of the Geronimo and Alligator Creeks Watershed Protection Plan. M&S presented a brief overview of the purpose of the study. Flood mitigation alternatives were discussed with regards to flood reduction effectiveness, costs, and benefit to the community. Preliminary locations for recommended detention ponds were shown. At the time of this meeting the benefits of the ponds were not calculated yet. It was thought that the ponds would not be shown as beneficial due to the minimal impact on the 1% Annual floodplain. The workshop consisted of many questions, comments, and concerns by the attendees.

### 1.5 FEMA Backup Data

Upon startup of this project the Effective FEMA FIS backup data was requested. The data in PDF format and was downloaded from a FEMA FTP site. The PDF was created from a microfiche hydraulic report. The hydraulic study was performed in the SCS (now NRCS) Water Surface Profile Model (WSP2) software. No WSP2 files were received, only the copies of the output. Dates on the model ranged from August 14, 1974 to February 13, 1976, with a hand written note that indicates the model was plotted on March 5, 1976.

The intent regarding the hydraulic model was to use the WSP2 data to rebuild the model in HEC-RAS. The stream flow information from the WSP2 model would be used to calibrate. After detailed review of the data it was discovered that a large section of the input data for numerous cross sections was missing. Due to an incomplete data set for the hydraulic model and no hydrological backup data, the decision was made to create new models. A new drainage study for the entire watershed was performed. As efforts began to create the HEC-RAS model for the streams, it was found that no existing topographic data was available for the Guadalupe County portion of the watershed. The City of New Braunfels provided 2-foot contour data for the Comal County segment of the watershed. After several months of trying to find topographic data, M&S contracted with Stewart Geo Technologies to have the area surveyed via aerial photogrammetric mapping.

# 2.0 HYDROLOGIC ANALYSIS

The computational method employed in this study was developed by the Natural Resource Conservation Service (formerly the Soil Conservation Service). It is typically referred to as the SCS method. The SCS method uses dimensionless hydrographs to approximate runoff rates per unit time for the duration of a storm event. The method uses the following input parameters to calculate peak runoff values: drainage area, time of concentration, synthetic storm/ precipitation data, land use, and curve number values. Each of these parameters is discussed in detail in the following sections.

Although there may exist reasons based on theory to chose one method over another, M&S staff chose its methods on much more pragmatic grounds. While these methods are widely accepted by the engineering community considerations were made based on familiarity with computational techniques and computer software, available data for model input, and approved methods by permitting agencies. The last consideration was the most important factor. Although, Guadalupe County, the other study participants, and the TWDB have no required methods; careful consideration was made regarding future submittals to FEMA. The methods and software used in this study are accepted by FEMA.

Hydrologic analysis includes the evaluation of the existing 50%, 20%, 10%, 4%, 2% and 1% annual chance (2, 5, 10, 25, 50 and 100-year, respectively) storm events. The basins were delineated using ArcGIS 9.3.1 and Arc Hydro Tools 9. Curve Numbers were generated manually using parcel data, soil data and aerial imaging. Time of concentration information was developed by hand using 2 ft contour data of the watershed. Peak flow rate estimates for each basin were calculated using Bentley PondPack 10. Floodplain modeling was completed using HEC-RAS 4.1.0 and compiled using HEC-GeoRAS 4.2.93 within ArcGIS.

## 2.1 Drainage Area Delineation

The Guadalupe County Geodatabase contains boundaries for the sub basins within the county, including the Alligator and Geronimo Creek watersheds. This was used as the outer boundary of the delineation process in Arc Hydro Tools 9. A digital elevation model (DEM) of this area was created using 2 ft contours provided by Comal County and M&S Engineering, LLC. Terrain preprocessing was done on the DEM to recondition it for watershed processing. Basins were created based on the FEMA river reach study limits. A study area begins where 1 square mile of land drains to a particular point. Catchments were generated for tributaries with a drainage area of 640 acres (1 sq. mi.) or larger. A total of 39 basins were created. These drainage basins were named by assigning a number 1 through 39 starting at the northernmost basin and working south. Alligator Creek is defined by Basins 1 through 11. Geronimo Creek is defined by Basins 12 through 39.

## 2.2 Time of Concentration

The time of concentration (Tc) is the time it takes for the most hydraulically remote point to contribute to the runoff of the drainage area under investigation. The method used to calculate this was based on Natural Resources Conservation Service Technical Release 55 (NRCS TR55).

Flow is characterized by three different types: sheet flow, shallow concentrated flow and open channel flow. Sheet flow Tc is based on Manning's roughness value over the path, flow length, slope, and the 2-yr 24 hr rain depths. Shallow concentrated flow Tc is calculated using velocity, slope, flow length, and cover type. Channel flow Tc is calculated using the hydraulic radius, flow area, wetted perimeter, velocity, slope, Manning's roughness and flow length.[1] These parameters were calculated by hand using aerial photography, 2 ft contours and ArcGIS.

The Manning's roughness values used were[2]:

| n-value | Description |
|---|---|
| 0.3 | 100% vegetated ground cover, bare soil or rock outcrops, min-med brush or tree cover. (sheet flow) |
| 0.02 | Asphalt. (sheet flow) |
| 0.045 | Natural Streams on plain, winding, some pools and shoals, some weeds and stones. |
| 0.04 | Cultivated areas – mature field crops. |
| 0.015 | Sewer with manholes, inlet, etc. |

The wetted perimeter and flow area were found using an iterative process. An initial guess was entered into the channel flow formula to get a Tc. With this the volume flow rate (Q) was calculated in Pondpack. The Q value was then entered into FlowMaster to find the wetted perimeter and flow area of the channel cross section. This was repeated until the change in Q was less than 5%. The equations used by Pondpack to find Tc can be found in Appendix B along with the Tc values that were calculated for each basin. The total travel time through the watershed was estimated to be approximately 14 hours.

## 2.3 Synthetic Storm/Precipitation Data

The precipitation data used in this analysis was derived from NWS NOAA Technical Paper No40 (Rainfall Frequency Atlas). Using this data, a synthetic storm was created in Pondpack, using the NRCS Type III 24-Hour Rainfall Distribution, for the 2-, 5-, 10-, 25-, 50- and 100-year storm events. Table 2-1 shows the design rainfall for these storms. These design storms were applied uniformly to each basin.

Table 2-1: NRCS Type III 24-Hour Rainfall Distribution for Guadalupe County[3]

| Duration | | Design Rainfall | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 Yr | 5 Yr | 10 Yr | 25 Yr | 50 Yr | 100 Yr |
| (minutes) | (hours) | (inches) | (inches) | (inches) | (inches) | (inches) | (inches) |
| 5 | 0.0833 | 0.61 | 0.76 | 0.86 | 1.00 | 1.09 | 1.24 |
| 15 | 0.2500 | 1.18 | 1.49 | 1.69 | 1.98 | 2.16 | 2.44 |
| 60 | 1.0000 | 2.01 | 2.58 | 2.98 | 3.50 | 3.90 | 4.34 |
| 120 | 2.0000 | 2.43 | 3.15 | 3.67 | 4.33 | 4.87 | 5.40 |
| 180 | 3.0000 | 2.69 | 3.49 | 4.10 | 4.85 | 5.48 | 6.07 |
| 360 | 6.0000 | 3.15 | 4.13 | 4.88 | 5.81 | 6.63 | 7.32 |
| 720 | 12.0000 | 3.67 | 4.83 | 5.77 | 6.90 | 7.96 | 8.75 |
| 1440 | 24.0000 | 4.24 | 5.62 | 6.79 | 8.16 | 9.51 | 10.43 |

[1] United States. *Urban Hydrology for Small Watersheds TR-55*. , 1986. Print.
[2] Chow, V.T. *Open-channel hydraulics:*. New York: McGraw- Hill Book Co., 1959. Print.
[3] Hershfield, David M. United States. *Technical Paper no. 40 Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*. , 1961. Print.

## 2.4 Land Use and Curve Numbers

The runoff curve numbers (CN) are the means by which land use is converted to runoff. Once rainfall values are calculated CN values are identified based on types of development and the conditions of the land. CN values are based on soils, plant cover, amount of impervious areas, interception, and surface storage.

Soils are classified into hydrologic soil groups (HSG's) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSG's, which are A, B, C, and D, are one element used in determining runoff curve numbers.[4]

Group A soils are sandy and well drained while group D soils are highly plastic clays that drain poorly. Groups B and C are in the intermediate ranges within the two extremes listed above. [5] Table 2-2 shows the CN values that were used.

Table 2-2: Alligator and Geronimo Watershed Curve Numbers[6]

| Cover Type | Curve Number for Soil Group | | |
|---|---|---|---|
| | B | C | D |
| Commercial Business | 92 | 94 | 95 |
| Fair condition (grass cover) | 69 | 79 | 84 |
| Grassland (fair) | 69 | 79 | 84 |
| Paved, open ditches | - | - | 93 |
| Residential >= 2 acres | 65 | 77 | 82 |
| Residential 1 acre | 70 | 79 | 84 |
| Residential 1/2 acre | 70 | 80 | 85 |
| Residential 1/3 acre | 72 | 81 | 86 |
| Residential 1/4 acre | 75 | 83 | 87 |
| Row Crops (SR+CR Good) | 75 | 87 | 90 |
| Woods (fair) | 60 | 73 | 79 |

Using county-provided parcel data and the NRCS soils map, CN values were assigned to each parcel depending on the land use and hydrologic soil group. In case of a parcel being on the boundary of one or more soil types, the soil group that was most dominant was chosen.

A weighted average was done on the CN values in each basin to obtain one CN value per basin. This was calculated automatically by Pondpack. CN values and their area within each watershed can be found in Appendix B.

Ultimate development models do not exist for the Alligator and Geronimo Creek Watersheds. To simulate this ultimate development, each basin was looked at separately. Within each basin, the amount of commercial, residential and paved areas are expected to increase while undeveloped land such as grassland and crop land would be expected to decrease. An exception to this is residential areas greater than 2 acres which is mainly ranch land. These were assumed to turn into residential subdivisions. An assumption was made that within each basin, the

[4] United States. *Urban Hydrology for Small Watersheds TR-55*. , 1986. 2-1. Print.
[5] Bedient, Phillip B. *Hydrology and Floodplain Analysis*. 2nd ed. Addison Wesley, 1992. 128. Print.
[6] United States. *Urban Hydrology for Small Watersheds TR-55*. , 1986. Print.

continued development would match the percentage of commercial, residential and paved areas that already exist. Undeveloped area was then divided among the developed areas based on how much of each type currently exists. Care was taken to make sure soil type was taken into account.

## 2.5 Peak Flow Summary

Pondpack was used to model the peak flows through each basin. The Modified Puls and Muskingum methods are the default routing methods are available in the PondPack software. The Modified Puls method was selected for its ability to be used with irregular channel cross section geometry. Channel cross sections and reach lengths were measured in ArcGIS. The time step used was 0.01 hours. Level pool routing was used for the detention study. Table 2-3 shows the peak flow values for each basin. Table 2-4 shows the cumulative Peak Discharge of Alligator and Geronimo Creeks.

Table 2-3: Peak Flow Rates for Alligator and Geronimo Creek in C.F.S.

| River | Basin | 2YR | 5YR | 10YR | 25YR | 50YR | 100YR |
|---|---|---|---|---|---|---|---|
| Alligator Creek | 1 | 1666.45 | 2504.99 | 3227.02 | 4084.26 | 4928.62 | 5502.81 |
| Alligator Creek | 2 | 962.90 | 1453.85 | 1877.08 | 2374.96 | 2865.47 | 3199.08 |
| Alligator Creek | 3 | 466.37 | 688.01 | 877.29 | 1098.78 | 1316.29 | 1464.12 |
| Alligator Creek | 4 | 626.05 | 927.96 | 1186.50 | 1489.57 | 1787.52 | 1989.98 |
| Alligator Creek | 5 | 969.70 | 1451.48 | 1867.31 | 2357.47 | 2840.39 | 3168.89 |
| Alligator Creek | 6 | 6.51 | 9.61 | 12.27 | 15.37 | 18.42 | 20.49 |
| Alligator Creek | 7 | 1395.93 | 2036.88 | 2584.50 | 3227.25 | 3859.03 | 4288.39 |
| Alligator Creek | 8 | 719.41 | 1021.27 | 1277.16 | 1575.47 | 1867.98 | 2066.56 |
| Alligator Creek | 9 | 1808.47 | 2618.72 | 3308.90 | 4116.83 | 4912.26 | 5452.80 |
| Alligator Creek | 10 | 827.10 | 1214.79 | 1547.11 | 1936.23 | 2318.59 | 2578.33 |
| Alligator Creek | 11 | 1378.13 | 2070.83 | 2668.99 | 3373.89 | 4071.28 | 4546.58 |
| Geronimo Creek | 12 | 1169.98 | 1722.27 | 2194.60 | 2748.07 | 3292.21 | 3662.00 |
| Geronimo Creek | 13 | 730.23 | 1074.03 | 1368.13 | 1712.59 | 2051.13 | 2281.15 |
| Geronimo Creek | 14 | 539.43 | 795.77 | 1015.64 | 1274.33 | 1529.40 | 1702.93 |
| Geronimo Creek | 15 | 279.84 | 411.91 | 524.94 | 657.40 | 787.64 | 876.14 |
| Geronimo Creek | 16 | 284.78 | 419.54 | 535.34 | 671.24 | 804.98 | 895.93 |
| Geronimo Creek | 17 | 839.49 | 1229.94 | 1566.26 | 1962.37 | 2354.05 | 2621.05 |
| Geronimo Creek | 18 | 417.51 | 615.49 | 785.11 | 984.12 | 1179.99 | 1313.52 |
| Geronimo Creek | 19 | 138.73 | 203.59 | 258.95 | 323.73 | 387.35 | 430.57 |
| Geronimo Creek | 20 | 32.20 | 47.27 | 60.12 | 75.17 | 90.00 | 100.09 |
| Geronimo Creek | 21 | 456.48 | 667.47 | 847.98 | 1059.64 | 1268.28 | 1410.24 |
| Geronimo Creek | 22 | 1590.44 | 2334.81 | 2973.71 | 3721.85 | 4456.97 | 4956.38 |
| Geronimo Creek | 23 | 676.07 | 990.93 | 1259.98 | 1576.31 | 1887.03 | 2098.07 |
| Geronimo Creek | 24 | 775.48 | 1149.46 | 1470.21 | 1848.20 | 2220.09 | 2472.89 |
| Geronimo Creek | 25 | 849.40 | 1252.71 | 1599.46 | 2006.73 | 2407.88 | 2680.80 |
| Geronimo Creek | 26 | 776.38 | 1155.95 | 1482.74 | 1867.19 | 2247.13 | 2505.90 |
| Geronimo Creek | 27 | 738.47 | 1089.90 | 1391.79 | 1746.78 | 2097.26 | 2335.81 |
| Geronimo Creek | 28 | 36.40 | 53.20 | 67.51 | 84.22 | 100.62 | 111.75 |
| Geronimo Creek | 29 | 541.63 | 806.55 | 1034.98 | 1303.89 | 1569.70 | 1750.80 |
| Geronimo Creek | 30 | 924.21 | 1375.78 | 1764.45 | 2221.60 | 2673.05 | 2980.64 |
| Geronimo Creek | 31 | 335.28 | 499.00 | 640.40 | 806.84 | 971.00 | 1082.76 |
| Geronimo Creek | 32 | 563.44 | 815.87 | 1031.17 | 1283.59 | 1531.68 | 1700.29 |
| Geronimo Creek | 33 | 1118.86 | 1680.87 | 2165.96 | 2737.98 | 3303.92 | 3689.33 |
| Geronimo Creek | 34 | 155.82 | 228.29 | 290.35 | 362.93 | 434.19 | 482.57 |
| Geronimo Creek | 35 | 596.06 | 845.60 | 1057.11 | 1304.01 | 1546.09 | 1710.44 |
| Geronimo Creek | 36 | 757.32 | 1125.83 | 1442.32 | 1814.00 | 2179.93 | 2428.78 |
| Geronimo Creek | 37 | 251.41 | 380.76 | 492.63 | 624.52 | 755.17 | 844.20 |
| Geronimo Creek | 38 | 484.62 | 701.02 | 885.64 | 1101.51 | 1313.53 | 1457.56 |
| Geronimo Creek | 39 | 682.92 | 1035.30 | 1340.27 | 1700.05 | 2055.29 | 2297.32 |

Table 2-4: Cumulative Peak Discharge for Alligator and Geronimo Creek in C.F.S.

| | Dist from Confluence | 2YR | 5YR | 10YR | 25YR | 50YR | 100YR |
|---|---|---|---|---|---|---|---|
| Alligator Creek | 149752.15 | 1666.45 | 2504.99 | 3227.02 | 4084.26 | 4928.62 | 5502.81 |
| | 149752.14 | 2563.60 | 3873.13 | 5002.02 | 6329.95 | 7638.10 | 8527.77 |
| | 145475.15 | 2374.66 | 3494.05 | 4796.33 | 6269.38 | 7717.71 | 8712.43 |
| | 145475.14 | 3000.71 | 4422.01 | 5971.38 | 7746.75 | 9466.52 | 10636.95 |
| | 145161.14 | 2997.51 | 4411.44 | 5960.31 | 7724.39 | 9466.36 | 10644.72 |
| | 145161.13 | 3876.16 | 5750.31 | 7628.32 | 9815.74 | 11942.58 | 13380.11 |
| | 119828.13 | 2623.28 | 3887.44 | 5071.23 | 6543.82 | 7823.13 | 8790.12 |
| | 119828.12 | 3248.10 | 4826.89 | 6191.33 | 7936.08 | 9494.28 | 10658.12 |
| | 97219.12 | 2960.84 | 4561.31 | 6099.88 | 8006.16 | 9887.37 | 11137.54 |
| | 97219.11 | 3227.24 | 4951.53 | 6572.81 | 8596.04 | 10600.53 | 11954.99 |
| | 79168.11 | 2991.65 | 4685.71 | 6467.70 | 8726.85 | 10978.51 | 12359.69 |
| Geronimo Creek | 79168.10 | 3678.91 | 5707.62 | 7702.59 | 10205.29 | 12660.32 | 14117.76 |
| | 72485.10 | 3702.17 | 5746.97 | 7750.96 | 10266.27 | 12725.95 | 14243.17 |
| | 72485.09 | 3979.29 | 6174.36 | 8337.14 | 11060.84 | 13771.00 | 15445.51 |
| | 65357.09 | 4061.00 | 6305.42 | 8504.75 | 11264.89 | 13973.88 | 15642.93 |
| | 65357.08 | 4334.30 | 6734.51 | 9051.73 | 11973.84 | 14857.50 | 16646.07 |
| | 64629.08 | 4338.17 | 6738.59 | 9056.27 | 11977.55 | 14859.75 | 16651.09 |
| | 64629.07 | 5353.06 | 8230.85 | 10837.45 | 14137.44 | 17464.43 | 19619.88 |
| | 61375.07 | 5376.04 | 8261.96 | 10872.96 | 14171.93 | 17464.78 | 19671.07 |
| | 61375.06 | 5486.93 | 8418.52 | 11062.50 | 14394.18 | 17727.29 | 19978.71 |
| | 47375.06 | 5989.53 | 9240.12 | 12144.37 | 15729.27 | 19384.48 | 21832.01 |
| | 47375.05 | 7386.25 | 11353.46 | 14857.78 | 19081.93 | 23450.73 | 26367.64 |
| | 34585.05 | 7537.12 | 11788.65 | 15515.59 | 19974.62 | 24560.28 | 27612.53 |
| | 34585.04 | 8959.35 | 14031.45 | 18482.08 | 23708.42 | 29073.65 | 32633.99 |
| | 29921.04 | 9181.69 | 14376.70 | 18962.28 | 24345.03 | 29864.25 | 33518.89 |
| | 29921.03 | 9567.80 | 14978.72 | 19762.45 | 25366.80 | 31104.72 | 34907.39 |
| | 26370.03 | 9558.16 | 14969.37 | 19765.07 | 25377.72 | 31099.70 | 34909.85 |
| | 26370.02 | 9717.06 | 15213.57 | 20089.82 | 25789.79 | 31602.36 | 35466.41 |
| | 13840.02 | 8852.04 | 14606.91 | 19589.68 | 25443.65 | 31391.78 | 35318.17 |
| | 13840.01 | 9265.94 | 15375.89 | 20691.86 | 26919.52 | 33245.72 | 37425.65 |
| | 10720.01 | 9313.65 | 15443.30 | 20785.12 | 27005.51 | 33258.78 | 37644.90 |
| | 10720.00 | 9455.69 | 15688.75 | 21136.17 | 27459.30 | 33813.13 | 38321.38 |
| | 0.00 | 9604.16 | 15688.75 | 21136.17 | 27459.30 | 33813.13 | 38321.38 |

# 3.0 HYDRAULIC ANALYSIS

## 3.1 Methodology

Cross section spacing for the hydraulic model was based on Paul Samuel's equation (Samuels, P.G., 1989. "Backwater lengths in rivers", Proceedings — Institution of Civil Engineers, Part 2, Research and Theory, 87, 571-582.). Bankful depth estimates were taken from within Alligator Creek and Geronimo Creek. An average cross section distance was found to be 500 ft. Using HEC-GeoRAS, cross sections for every reach were created by hand.

Bank stations were added through HEC-GeoRAS by mapping out the banks from an aerial photo of the watershed. The bank lines were measured by hand and inserted into the HEC-RAS model after it was created by HEC-GeoRAS.

Fifty-four bridges and low water crossings were studied in the Geronimo and Alligator creek watershed. There were a small number of other bridges and water crossings that were on private property which were simplified or ignored for this project. Of note are the I-35 culverts in Basin 8 that go underneath the Creekside Way development. Due to the complex geometry and drainage occurring through these culverts, it is not possible to accurately portray its flow without further study. Table 3-1 lists the bridges and water crossings that were studied.

Surveyed bridges were modeled in HEC-RAS at the height at which they were surveyed. The bridge deck was tied back into the road profile which was obtained from HEC-GeoRAS outside of the bridge survey extents. Upstream and downstream cross sections were modified as needed to define the channel and place the invert of the opening properly. Site visits were conducted at crossings which were not surveyed. Measurements taken at these crossings include culvert dimensions and vertical distance from the road deck.

Table 3-1: Bridges and Low Water Crossings Studied in Alligator and Geronimo Creek

| Stream | Reach | Stream Station | Description |
|---|---|---|---|
| Alligator Creek | 6 | 220.2640 Hoffmann Ln | Hoffmann Ln. |
| Alligator Creek | 7 | 21614.83 FM 1102 | FM 1102 |
| Alligator Creek | 7 | 11959.56 Gooodwin Ln | Gooodwin Ln |
| Alligator Creek | 7 | 5955.235 IH 35 (Main Road | IH 35 (Main Road) |
| Alligator Creek | 7 | 5835.668 IH 35 (Northboun | IH 35 (Northbound Access Road) |
| Alligator Creek | 7 | 6070.973 IH 35 (Southboun | IH 35 Southbound Access Road) |
| Alligator Creek | 8 | 3684.417 IH 35 N (Target) | IH 35 N (Target) |
| Alligator Creek | 9 | 18818.89 FM 1101 | FM 1101 |
| Alligator Creek | 9 | 512.7987 Schwarzlose Rd | Schwarzlose Rd |
| Alligator Creek | 9 | 12179.1  Westmeyer Rd | Westmeyer Rd |
| Alligator Creek | 11 | 10705.84 Barbarossa Rd | Barbarossa Rd |
| Alligator Creek | 11 | 13530.24 FM 758 | FM 758 |
| Alligator Creek | 11 | 2185.628 Huber Rd | Huber Rd |
| Geronimo Creek | 12 | 4494.543 HWY 123 N | HWY 123 N |
| Geronimo Creek | 12 | 3269.041 Thormeyer Rd | Thormeyer Rd |
| Geronimo Creek | 16 | 3404.278 Geronimo Dr | Geronimo Dr |
| Geronimo Creek | 16 | 2443.984 Heinemeyer Rd | Heinemeyer Rd |
| Geronimo Creek | 16 | 4240.247 HWY 123 N | HWY 123 N |
| Geronimo Creek | 17 | 5313.559 Barbarossa Rd | Barbarossa Rd |
| Geronimo Creek | 17 | 1083.083 Huber Rd | Huber Rd |
| Geronimo Creek | 17 | 9348.906 Pieper Rd | Pieper Rd |
| Geronimo Creek | 18 | 6094.869 FM 2623 | FM 2623 |
| Geronimo Creek | 18 | 2453.47  Heinemeyer Rd | Heinemeyer Rd |
| Geronimo Creek | 21 | 2876.437 HWY 123 N | HWY 123 N |
| Geronimo Creek | 25 | 12569.19 Glenwinkel Rd | Glenwinkel Rd |
| Geronimo Creek | 25 | 8115.275 Timmermann Rd | Timmermann Rd |
| Geronimo Creek | 26 | 8215.094 FM 20 | FM 20 |
| Geronimo Creek | 26 | 7829.957 Ilka Switch | Ilka Switch |
| Geronimo Creek | 26 | 12623.76 Laubach Rd | Laubach Rd |
| Geronimo Creek | 26 | 20681.18 Timmermann Rd | Timmermann Rd |
| Geronimo Creek | 27 | 1637.609 Haberle RD | Haberle RD |
| Geronimo Creek | 27 | 10050.53 HWY 123 N | HWY 123 N |
| Geronimo Creek | 27 | 4023.071 Willmann Rd | Willmann Rd |
| Geronimo Creek | 29 | 4547.385 FM 20 | FM 20 |
| Geronimo Creek | 29 | 10488.67 Laubach Rd | Laubach Rd |
| Geronimo Creek | 30 | 7791.949 HWY 123 N and Co | HWY 123 N and Cordova Rd Intersection |
| Geronimo Creek | 30 | 7753.43  HWY 123 N and La | HWY 123 N and Laubach Rd Intersection |
| Geronimo Creek | 30 | 1754.984 Laubach Rd | Laubach Rd |
| Geronimo Creek | 32 | 6107.988 East Martindale | East Martindale Rd |
| Geronimo Creek | 33 | 4521.891 Baer Creek Trl | Baer Creek Trl |
| Geronimo Creek | 33 | 3090.634 East Walnut St | East Walnut St |
| Geronimo Creek | 33 | 14067.64 IH 10 E | IH 10 E |
| Geronimo Creek | 33 | 14337.06 IH 10 E Northern | IH 10 E Northern Access Rd |
| Geronimo Creek | 33 | 13566.6  IH 10 E Southern | IH 10 E Southern Access Rd |
| Geronimo Creek | 33 | 13060.61 Sunbelt Rd | Sunbelt Rd |
| Geronimo Creek | 33 | 1356.759Alternate 90 | Alternate 90 |
| Geronimo Creek | 34 | 3385.687 IH 10 E Eastboun | IH 10 E Eastbound |
| Geronimo Creek | 34 | 3497.879 IH 10 E Westboun | IH 10 E Westbound |
| Geronimo Creek | 35 | 1623.926 Railroad Bridge | Railroad Bridge |
| Geronimo Creek | 36 | 1189.034 East Court St/Al | East Court St / Alt 90 |
| Geronimo Creek | 36 | 10701.42 E kingsbury St/U | East kingsbury St / US 90 |
| Geronimo Creek | 36 | 2300.292 East Walnut St | East Walnut St |
| Geronimo Creek | 38 | 3270.17  Elmwood Dr | Elmwood Dr |
| Geronimo Creek | 38 | 1916.548 Monterey Oak | Monterey Oak |

*Grey – Detailed Survey conducted
**White – Measured in field

### 3.2 Hydraulic Model Verification

Model calibration and verification was completed through five different methods: community input, Effective FEMA floodplain comparison, 1974 Study data, flood insurance claims, and historical bridge high water marks obtained from G.B.R.A.

Community input was taken at a public meeting with local residents. Residents marked where there was flooding, loss of power, property damage and well as the lack of flooding if they lived near a flood prone area. These locations were checked against the proposed 100-Year floodplain generated by M&S. It was found that this information depicted the proposed floodplain to a good degree.

Flood insurance claims were located and overlaid on the proposed floodplain. These claim locations fit very well with the proposed 100-Year inundation pattern.

The Effective FEMA floodplain was created from a study conducted in 1974. This floodplain was produced with less-detailed information and it used the WSP2 program which is now retired. Some of the documentation from the model has been lost over the years making it impossible to fully replicate the results today. The flow values that were recoverable were placed in the HEC-RAS model and mapped with up-to-date topography. This new 1974 floodplain was then overlaid on the current 1974 FEMA maps and on the proposed floodplain generated by M&S. The differences seen between these two floodplains were expected. This floodplain comparison can be seen in Appendix A – Exhibit 7.

As mentioned, historical bridge high water marks for Geronimo Creek were obtained from GBRA. Elevations were converted to NAVD 88 as needed. As can be seen in Table 3-2, elevation differences range from 1.5 to -2.8 ft.

Table 3-2: High Water Marks Verification

| Description | Date Event | Recorded HWM | Adjusted NAVD 88 Elev | Prop Upper Elev | Elev Diff |
|---|---|---|---|---|---|
| Schwartzlose Rd, nail in elect pole | 10/17/1998 | 619.8 | 620.1 | 619.5 | -0.6 |
| Huber Rd, nail in elect pole | 10/17/1998 | 592.1 | 592.4 | 592.5 | 0.1 |
| HWY 123 Bridge, nail in elect pole | 10/17/1998 | 580.0 | 580.3 | 577.5 | -2.8 |
| HWY 20 Bridge, wooden stake | 10/17/1998 | 523.4 | 523.7 | 522.2 | -1.5 |
| HWY 20 Bridge, wooden stake in drainage ditch | 10/17/1998 | 520.5 | 520.8 | 522.2 | 1.4 |
| HWY 90 Bridge, nail in tree (E Kingsbury) | 10/17/1998 | 498.7 | 499.0 | 498.0 | -0.9 |
| HWY 90 Bridge, nail in tree (E Kingsbury) | 10/17/1998 | 497.8 | 498.1 | 498.0 | 0.0 |
| HWY 90A Bridge, nail in tree (E Court St) | 10/17/1998 | 481.6 | 481.9 | 483.3 | 1.5 |

A comparison between the effective FEMA floodplain and the proposed floodplain showed some interesting results. The FEMA study conducted in Comal County had overestimated WSELs while the Guadalupe County study had underestimated WSELs as can be seen in Table 3-3. This can be caused by any number of things including different n values, cross section spacing, bridge changes, better survey methods, and more detailed floodplain modeling methods, to name a few. The water surface elevation change calculated for East Court Street seemed quite large. Further study revealed that the proposed elevation fit much closer to the verification data that was collected than the Effective elevation did.

Table 3-3: FEMA Floodplain and Proposed Floodplain Elevations

| County | Location | Cross Section | Effective WSEL | Proposed WSEL | Elevation Difference |
|---|---|---|---|---|---|
| Comal County | **Alligator Creek** | | | | |
| Comal County | Hoffmann Ln | W | 717 | 714 | -3 |
| Comal County | 1300 Ft D.S. of Rd | V | 712 | 709 | -3 |
| Comal County | 2600 Ft D.S. of Rd | U | 711 | 705 | -6 |
| Comal County | Fm 1102 | T | 711 | 702 | -9 |
| Comal County | 1600 Ft D.S. of Rd | R | 700 | 697 | -3 |
| Comal County | 3300 Ft D.S. of Rd | Q | 695 | 692 | -3 |
| Comal County | 5400 Ft D.S. of Rd | P | 689 | 687 | -2 |
| Comal County | 7400 Ft D.S. of Rd | O | 684 | 682 | -2 |
| Comal County | Goodwin Ln | N | 682 | 680 | -2 |
| Comal County | 2200 Ft D.S. of Rd | L | 675 | 674 | -1 |
| Comal County | 4100 Ft D.S. of Rd | K | 673 | 671 | -2 |
| Comal County | I-35 | J | 670 | 668 | -2 |
| Comal County | 18900 Ft D.S. of Rd | I | 630 | 632 | 2 |
| Comal County | Schwarzlose | H | 619 | 619 | 0 |
| Comal County | Fm 768 | F | 615 | 613 | -2 |
| Guadalupe County | Barbarossa Rd | D | 606 | 608 | 2 |
| Guadalupe County | Huber Rd | B | 592 | 594 | 2 |
| Guadalupe County | **Geronimo Creek** | | | | |
| Guadalupe County | 1900 Ft D.S. of Rd | M | 588 | 592 | 4 |
| Guadalupe County | Hwy 123 | L | 574 | 578 | 4 |
| Guadalupe County | Heinemeyer Rd | J | 572 | 573 | 1 |
| Guadalupe County | Glenewinkel Rd | I | 560 | 560 | 0 |
| Guadalupe County | Timmermann Rd | | 550 | 553 | 3 |
| Guadalupe County | Laubach Rd | | 528 | 535 | 7 |
| Guadalupe County | FM 20 | G | 515 | 522 | 7 |
| Guadalupe County | E Kingsbury St | E | 492 | 499 | 7 |
| Guadalupe County | Court St | C | 484 | 472 | -12 |
| Guadalupe County | 11700 Ft D.S. of Rd | A | 464 | 465 | 1 |

## 3.3 Model Limitations

During the larger flood events, it was found that water from some stream reaches was overflowing across the ridge that separates it from a neighboring reach. This occurs in a few areas where two reaches come together. Lateral weirs were added to the model, but the model continually failed to converge during optimization. It was decided that the model is more accurate without lateral weirs than with them not working properly. Currently there are four areas where the water surface elevation contours do not appear natural due to the lack of weirs. This will need to be resolved prior to any submissions to FEMA for map revisions. There are a few smaller bridges which did not get surveyed due to funding constraints. These bridges will need to be surveyed and updated in the model if submitted to FEMA.

# 4.0 PROBLEM AREA IDENTIFICATION

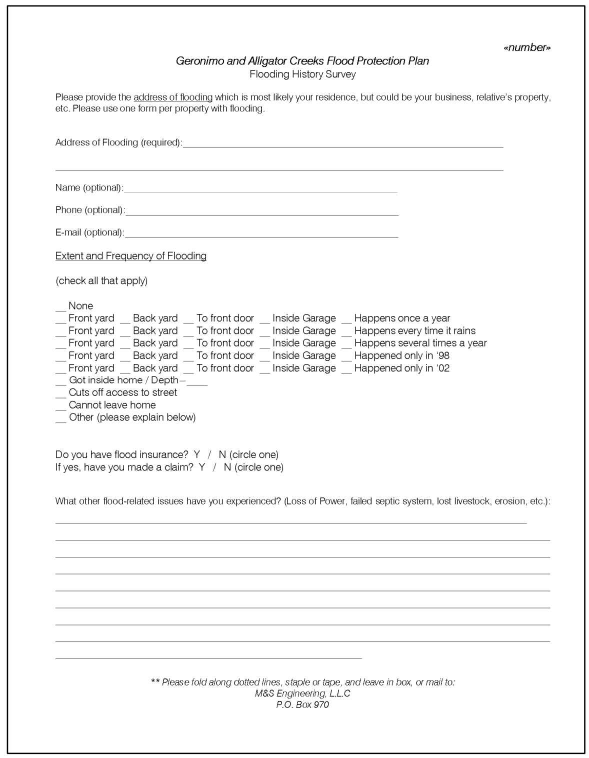
The identification of areas that are prone to flooding or flood damage is an effective tool in the initial planning of flood mitigation alternatives. Problem areas are used to geographically concentrate the flood reduction effort in order to achieve the maximum beneficial impact. Several different methods were used to identify and locate problem areas. The following sections will describe in detail the methods used.

## 4.1 Public Input & Location of Problem Areas

During the first public meeting residents and property owners were asked to fill out a Flooding History Survey in which information was requested regarding locations of flooding, extent of flooding, and frequency of flooding. Many people took surveys back to neighbors who were unable to attend the meeting. Numerous surveys were received by mail.

Residents and property owners were asked to locate on a map, using numbered stickers, the area(s) that they described in the Flooding History Survey. The numbered stickers corresponded to a number on the Flooding History Survey. This allowed the problem area to be cross referenced to the survey and located graphically in case there was a poor description or no address was given.

After the meeting the problem areas were input into GIS to create a digital version of the map created at the public meeting. The information on the Flooding History Surveys was entered into attribute tables associated with each location. A sample Flooding History Survey is shown in Figure 4-1.



«number»

*Geronimo and Alligator Creeks Flood Protection Plan*
Flooding History Survey

Please provide the address of flooding which is most likely your residence, but could be your business, relative's property, etc. Please use one form per property with flooding.

Address of Flooding (required):______________________________

Name (optional):______________________________

Phone (optional):______________________________

E-mail (optional):______________________________

Extent and Frequency of Flooding

(check all that apply)

__ None
__ Front yard __ Back yard __ To front door __ Inside Garage __ Happens once a year
__ Front yard __ Back yard __ To front door __ Inside Garage __ Happens every time it rains
__ Front yard __ Back yard __ To front door __ Inside Garage __ Happens several times a year
__ Front yard __ Back yard __ To front door __ Inside Garage __ Happened only in '98
__ Front yard __ Back yard __ To front door __ Inside Garage __ Happened only in '02
__ Got inside home / Depth–____
__ Cuts off access to street
__ Cannot leave home
__ Other (please explain below)

Do you have flood insurance? Y / N (circle one)
If yes, have you made a claim? Y / N (circle one)

What other flood-related issues have you experienced? (Loss of Power, failed septic system, lost livestock, erosion, etc.):

*** Please fold along dotted lines, staple or tape, and leave in box, or mail to:*
*M&S Engineering, L.L.C*
*P.O. Box 970*

Figure 4-1: Sample Flooding History Survey

## 4.2 Stream Crossing Ranking

Alligator and Geronimo Creeks have a combined total of 27 structures that cross the main stream channel. For the purposes of this study a crossing defined as: public roadway with culvert, public low water crossing, public bridge, and railroad tracks. Each stream crossing was evaluated using ten criteria. Table 4-1 shows a list of the criteria. No private drives, culverts or bridges were included in the evaluation. Railroad crossings were identified but not ranked.

M&S staff ranked the ten criteria based on the level of importance each criterion had with respect to assessing problems at stream crossings. Each individual ranked the criteria on scale of zero to nine; zero being the least important and nine the most important. The total number of points each criterion received was divided by the total maximum points possible. The result was a weighted average that ranked the criteria based on the highest score. Table 4-2 shows the results of the criteria ranking.

The next step in ranking the stream crossings was to set up a decision matrix that totals the scores for each criterion per steam crossing. In order to do this a numerical scoring system was established. Each criterion was scored based on parameters that assigned levels of importance according to the functionality, condition, or threat of the stream crossing. Tables in Appendix E show the parameters used to score the criteria for each roadway.

The top 5 ranked crossings were identified based in the 5 highest scores. A high score indicated that a roadway is inadequate based on the chosen criteria, and was evaluated to determine if modifications would be favorable in reducing the frequency and extent of flooding. Tables 4-3 and 4-4 show the results of the ranking process.

Table 4-1 Evaluation Criteria

| ID. | Description |
|---|---|
| C1 | Restriction of Emergency Access During Flood Events |
| C2 | Threat to Adjacent Upstream Habitable Structures |
| C3 | Frequency of Reported Road Closures |
| C4 | Condition of Crossing |
| C5 | Ratio of Structure Opening Area to Drainage Area |
| C6 | Severity of Erosion Condition |
| C7 | Severity of Debris Obstruction |
| C8 | Severity of Sediment Obstruction |
| C9 | Drainage Area Contributing to Crossing |
| C10 | Hydraulic Adequacy (frequency of overtopping) |

Table 4-2 Criteria Rank

| ID. | Description | Weight | Rank |
|---|---|---|---|
| C1 | Restriction of Emergency Access During Flood Events | 0.2 | 1 |
| C2 | Threat to Adjacent Upstream Habitable Structures | 0.16 | 2 |
| C3 | Frequency of Reported Road Closures | 0.15 | 3 |
| C4 | Condition of Crossing | 0.12 | 4 |
| C10 | Hydraulic Adequacy (frequency of overtopping) | 0.1 | 5 |
| C6 | Severity of Erosion Condition | 0.09 | 6 |
| C5 | Ratio of Structure Opening Area to Drainage Area | 0.08 | 7 |
| C9 | Drainage Area Contributing to Crossing | 0.05 | 8 |
| C7 | Severity of Debris Obstruction | 0.03 | 9 |
| C8 | Severity of Sediment Obstruction | 0.02 | 10 |

Table 4-3: Top 5 Ranked Stream Crossings

| Location | Crossing ID | Score |
|---|---|---|
| Huber Rd | A11 | 1.76 |
| Laubach Rd | G9 | 1.58 |
| CR 122 Geronimo Dr | G5 | 1.43 |
| Barbarosa Rd | A10 | 1.40 |
| Heinemeyer Rd | G6 | 1.39 |

# Table 4-4: Scoring Results

| | Location | Crossing ID | C1 Restriction of Emergency Access During Flood Events | C2 Threat to Adjacent Upstream Habitable Structures | C3 Frequency of Reported Road Closures | C4 Condition of Crossing | C5 Ratio of Drainage Area to Structure Opening Area | C6 Severity of Erosion Condition | C7 Severity of Debris Obstruction | C8 Severity of Sediment Obstruction | C9 Drainage Area Contributing to Crossing | C10 Hydraulic Adequacy (frequency of overtopping) | Total Weighted Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Criteria Weights | | | 0.2 | 0.16 | 0.15 | 0.12 | 0.08 | 0.09 | 0.03 | 0.02 | 0.05 | 0.1 | |
| Alligator Creek | FM 1102 | A1 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 1.04 |
| | RR Track North | A2 | Not Scored | | | | | | | | | | |
| | RR Track South | A3 | | | | | | | | | | | |
| | Goodwin Lane | A4 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0.74 |
| | IH-35 | A5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0.17 |
| | FM 1101 | A6 | 0 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 3 | 0.79 |
| | CR 139 Westmeyer Rd | A7 | 0 | 1 | 0 | 1 | | 0 | 0 | 0 | 1 | 3 | 0.63 |
| | Schwarzlose Rd | A8 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 3 | 0.92 |
| | FM 758 | A9 | 1 | 3 | 0 | 1 | 1 | 1 | 0 | 0 | 2 | 3 | 1.37 |
| | Barbarosa Rd | A10 | 2 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 3 | 1.40 |
| | Huber Rd | A11 | 3 | 3 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 3 | 1.76 |
| Geronimo Creek | CR 130 | G1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0.42 |
| | Barbarosa Rd | G2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0.38 |
| | Huber Rd | G3 | 1 | 2 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 3 | 1.26 |
| | HWY 123 | G4 | 0 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 2 | 0.90 |
| | CR 122 Geronimo Dr | G5 | 1 | 2 | 1 | 1 | 3 | 0 | 0 | 0 | 2 | 3 | 1.43 |
| | Heinemeyer Rd | G6 | 0 | 3 | 1 | 1 | 3 | 0 | 0 | 0 | 2 | 3 | 1.39 |
| | Glenewinkel Rd | G7 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 3 | 0.83 |
| | Timmerman Rd | G8 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 3 | 0.80 |
| | Laubach Rd | G9 | 1 | 2 | 2 | 1 | 3 | 0 | 0 | 0 | 2 | 3 | 1.58 |
| | FM 20 | G10 | 0 | 3 | 0 | 1 | 2 | 0 | 0 | 0 | 3 | 3 | 1.21 |
| | IH-10 | G11 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 3 | 0 | 0.43 |
| | RR Track | G12 | Not Scored | | | | | | | | | | |
| | Hwy 90 Kingsbury St | G13 | 0 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 3 | 0 | 0.75 |
| | Walnut St | G14 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 3 | 3 | 0.73 |
| | Hwy 90 Court St | G15 | 0 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 3 | 3 | 1.05 |

## 4.3 National Flood Insurance Program Claim Locations

Locating structures that file flood insurance claims provides valuable geographic referencing to identify problem areas. National Flood Insurance Program (NFIP) claim data for the project area was provided by the TWDB. The data was used solely for locating structures that have made claims and all structures were represented by a symbol on a map. No private information was released or published for the policy holders.

The locations of the claims proved to be a valuable tool in which to prioritize problem areas. Claim locations also assisted greatly in the validation of the hydraulic model.

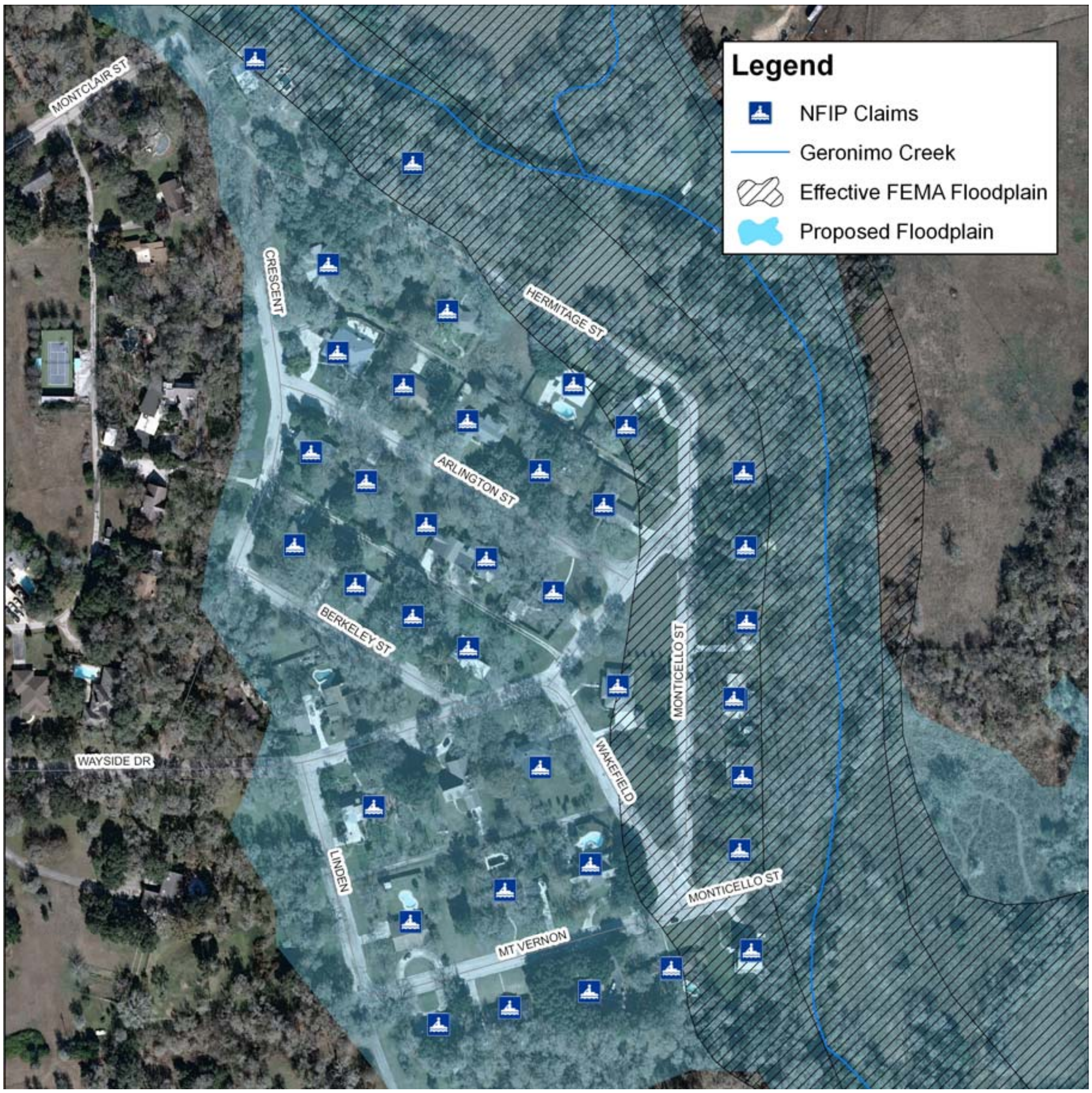



Figure 4-2: NFIP Claim Locations—Elmwood Subdivision, Seguin, TX

## 5.0 FLOOD MITIGATION ALTERNATIVE EVALUATIONS

Potential flood mitigation alternatives were identified by the Oversight Committee to be evaluated for effectiveness in reducing floodplain elevations, reducing/preventing flood damage, and providing cost-beneficial impacts. The options explored as part of this study included: channel modifications, brush removal, stream crossing improvements, regional detention ponds, regional detention regulations, flood early warning system, and buyouts for repetitive loss structures.

### 5.1 Channel Modifications

Initially channel modifications were modeled in proximity to identified problem areas and stream crossings to evaluate the effects. No localized effects were seen in the water surface elevations of any storm frequency. Next a regional approach was explored. An exaggerated cross section was used to create a modified channel the entire length of Geronimo Creek to see what the effects would be. Again no impacts to the water surface elevations were observed. It was determined that the flow area of the cross sections were so large that adding wide channels resulted in a negligible increase to the flow area, thus not constituting any benefit and resulting in a decision to not pursue this option.

### 5.2 Brush Removal

The findings of the evaluation removing brush from stream beds and overbank areas were similar to that of the channel modifications. By reducing the Manning's friction coefficients in the hydraulic model the clearing of brush and debris can be simulated. Aerial photos were used to target areas of dense trees and underbrush for removal. The model was modified to reflect a lower Manning's n-value for a 100-foot wide clearing and the effects were non-measurable.

### 5.3 Stream Crossing Improvements

The opportunity to make structural modifications or upgrades to roads and bridges can have very beneficial impacts for local residents, county road crews, and emergency service agencies. Roadway modifications and culvert upgrades, while beneficial to traffic flow and reduction of risk to life, do not reduce the occurrence or magnitude of flooding.

The top 5 ranked stream crossings were evaluated in detail to determine if reasonable improvements would allow for increased conveyance of stormwater under the roadway. Increased conveyance may possibly reduce the depth, frequency, or even the occurrence of flood water over the road. The 5 stream crossings were iteratively modified in HEC-RAS to determine the effects on the water surface elevations over the road.

Three considerations were found to be true in analyzing the roadways. The first is that the majority of the roads have limiting slopes and can not be raised without creating high spot in the road that causes the floodwater to seek an alternate path around. The second consideration is that the bridges analyzed could not be significantly raised without created increased threat of backwater to upstream and adjacent structures. The final consideration is that due to the previous two concerns it is not economically feasible to construct culverts or bridge sections to convey enough flood water to reduce the magnitude and frequency at which the roads overtop. Based on these considerations it was determined that upgrading culverts and raising roadways would have a negligible benefit based on the cost of the improvements.

## 5.4 Regional Detention Ponds

In order to evaluate the effectiveness of detention as a flood mitigation strategy, a large number of possible detention pond configurations were modeled. Locations for possible ponds were selected based on potential availability of land and likelihood of beneficial timing effects. These ponds were all designed to be offline from the main stream, with an inlet weir to control inflow rates. The inlet weir elevations are set above the channel overbank elevation to allow base stream flow to bypass the pond. The water surface elevation of the pond was designed to be lower than the weir elevation, which ensures that there will be no backwater effect of the pond on the stream.

It was found that the floodplain was fairly resistant to decreases in flood flows, which necessitates large decreases in discharge to reduce water surface elevations, thus requiring large detention volumes. Large detention volumes dictate construction of large ponds, which consequently can have high construction costs.

When analyzing the benefits due to the flood reduction it was found that the current development conditions cause low benefits. The middle section of the Geronimo Creek currently consists of rural subdivisions, small communities, and much undeveloped agricultural land. By comparing the benefits of reducing water surface elevations to the expected construction costs, the results showed a benefit-cost ratio well below the desired 1.0. However, future benefits may also be considered by alternate means of analysis to show the construction of the ponds more beneficial.

The following sections describe in detail the methods used to analyze and model the size, location, and effects of the detention pond options. In addition, explanations and rationale are detailed below in order to illustrate the distinctive characteristics of the watersheds.

### 5.4.1 Model Set Up

The detention ponds were modeled and analyzed using a combination of software. The foundational watershed model was created in PondPack to provide hydrological and timing calculations. HEC-RAS was used for weir inlet hydraulic calculations. Excel was used for hydrograph creation calculations. The modeling process is described below.

The ponds were first modeled individually and separate from the larger stream model to determine efficient pond depths and peak inlet flows given the area and total fall available. A range of approximate inflow hydrographs were used to determine if there is an optimum inflow rate resulting in greater flow reduction capabilities. Simple orifices were used for the pond outflows. The pond bottom depth and orifice inverts, diameters, and number were determined by trial and error to achieve the highest possible reduction in peak outflow rate.

Once workable pond geometries had been determined, a complete proposed PondPack model was created. As PondPack does not allow for split flow, the model must be broken into smaller sections, with an outfall just upstream of each pond. Each new section begins with a hydrograph routed through a pond, as well as a hydrograph representing the flow in the main stream which bypasses the pond. These hydrographs are calculated in Excel.

In order to construct a reasonable pond inflow hydrograph, a preliminary lateral weir was modeled in HEC-RAS at the location of each proposed pond. Using this weir, a table relating pond inflow rates to total stream flow rates was developed.

Once the weir relationship had been determined, the hydrograph for the flows at this location just upstream of the pond was imported from PondPack. For each value in the flow rate table, the times at which the total stream flow occurs is identified. When paired with the weir inflow Q's, these times proved a rough pond inflow hydrograph. However, in order to be imported back into PondPack, a more complete hydrograph with a small, uniform timestep is required. Therefore an equation based on polynomial regression is generated to match the determined hydrograph within the upper and lower time bounds. The equation generator PolySolve Version 3.3 developed by Paul Lutus was used. This tool requires judgment on what constitutes a reasonable data fit, and often requires additional interpolated points to assist in the equation solving.

Finally, this inflow hydrograph is subtracted from the main stream hydrograph to determine what flow bypasses the pond.

As the flows at each location will be affected by upstream ponds, these pond hydrographs must be developed consecutively, starting at the top of the watershed. As each pair of hydrographs is created, it is entered into the model so that the starting hydrograph for the next pond takes into account the effects of the upstream ponds.

This complete model accounts for both the direct reduction in peak flow due to the detention pond, as well as the indirect effects based on the timing of detention pond release.

### 5.4.2 Limitations

This process is sufficient for the present task of identifying general pond effectiveness and evaluating the timing effects of multiple ponds. If detailed design specifications for a specific pond configuration will be prepared, the pond geometries and outfalls will have to be carefully set to match real-world constraints and the weirs adjusted for maximum effectiveness. The final characteristics of the weir will affect the inflow hydrograph which will in turn affect the pond outflow, and so results will need to be iterated through the process several times to achieve consistent flow values.

The ponds as currently modeled are simplified and idealized. Real-world pond geometry considerations such as topological constraints, bottom slopes, available depths, and outlet structure design will affect pond efficiency.

### 5.4.3 Results

In the course of this analysis, several general relationships were revealed. These provide a useful rule of thumb for the purposes of planning and determining the feasibility of detention options within the Geronimo Creek watershed.

The first relationship of note is between flow rate (measured in cfs) and flood depth (measured in feet). Figures 5-1 and 5-2 plot this relationship for two representative cross sections. From these it can be seen that the 100-year floodplain is fairly resistant to changes. A large reduction in flow rate corresponds to a comparatively small change in flood depth. For smaller storm events, a reduction in flow rates has a comparatively larger effect. Within the Geronimo Creek/Alligator Creek Watershed, as a rule of thumb, for the 100-year storm event to achieve a 1 foot reduction in floodplain elevation requires a 4000 cfs reduction of flow rate. For the 10-year storm event to achieve a 1 foot reduction in floodplain elevation requires a 2500 cfs reduction of flow rate.

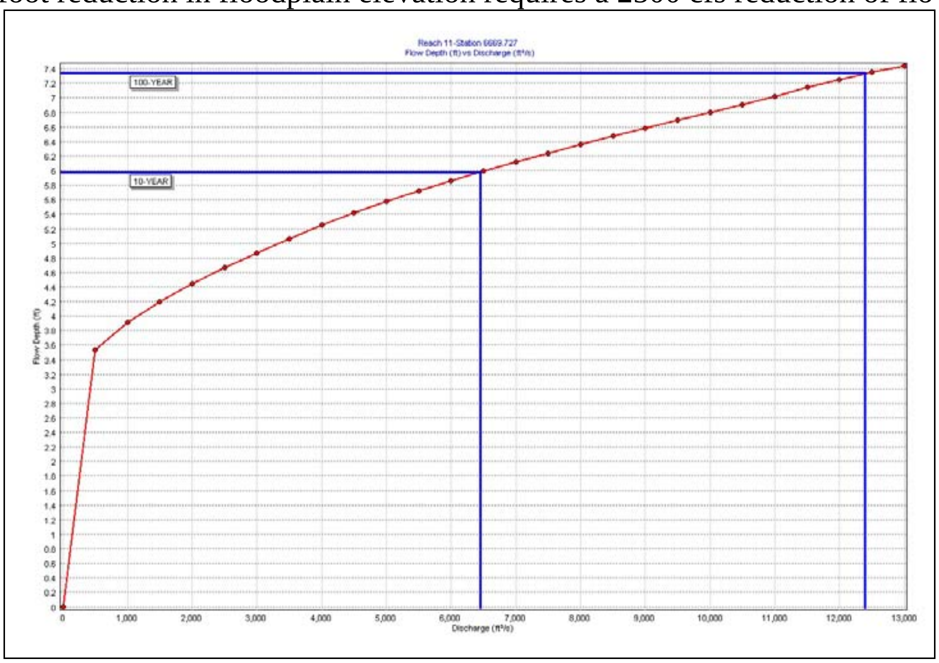


Figure 5-1: Alligator Creek Flow Depth vs. Discharge

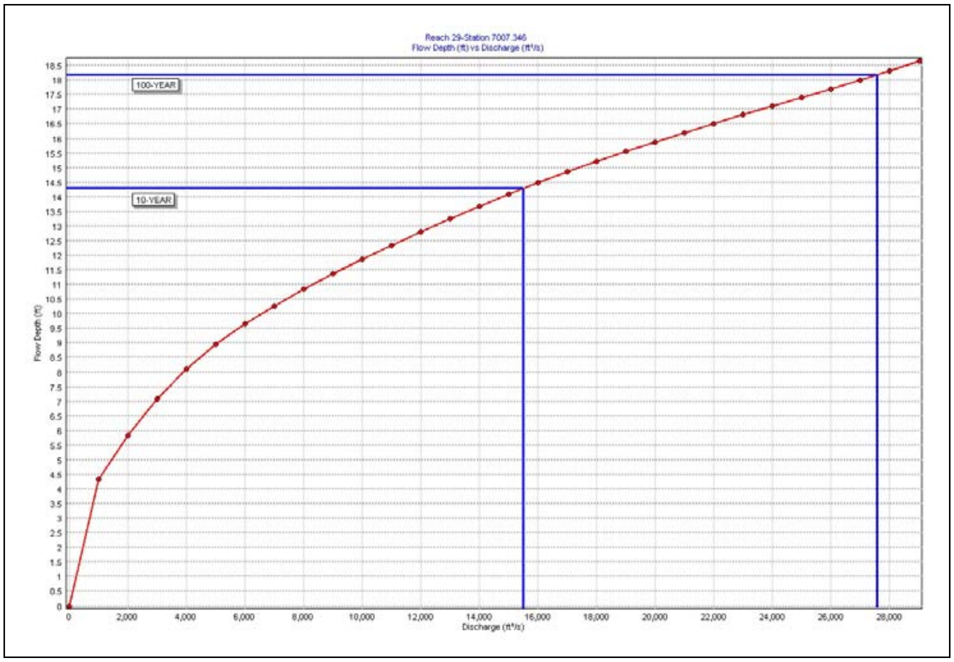



Figure 5-2: Geronimo Creek Flow Depth vs. Discharge

The second useful relationship is between total storage volume and peak flow reduction. Figure 5-3 shows a four-pond scenario designed to reduce the 25-year peak flows by up to 4000 cfs within Geronimo Creek. Pond efficiency, measured as the ratio of flow reduction to storage volume, varies from approximately 1.3 to 2.3. (Alligator Creek exhibits more complex behavior and is discussed below.) This pattern was found to hold across many pond configurations. Consequently, a second rule of thumb is that 1 acre-ft of storage yields a peak flow reduction of 1.5 cfs.

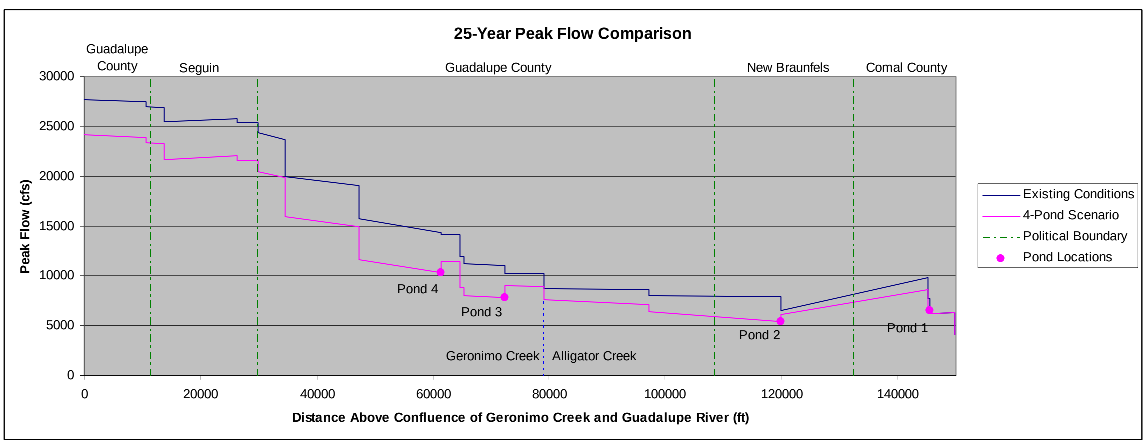



Figure 5-3: 25-Year (4% annual) Peak Flow Comparison

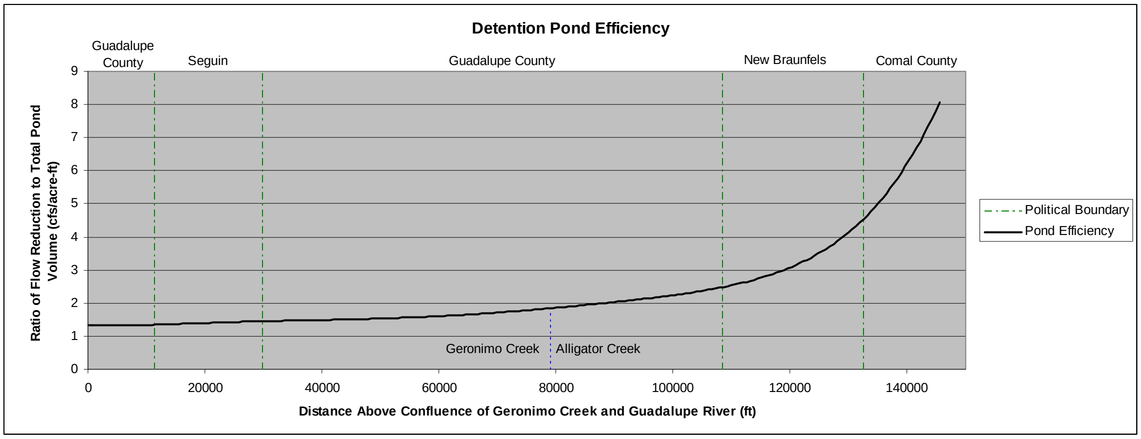



Figure 5-4: Detention Pond Efficiency

A further discovery is that Alligator Creek is hydrologically distinct from Geronimo Creek. The contributing drainage basins to the upper region of Alligator Creek peak at nearly the same time, which results in a very sharply defined hydrograph. This is naturally attenuated while travelling the length of Reaches 7 and 9. Figure 5-5 illustrates this by comparing the hydrograph at 145,161 ft, in the upper portion of Alligator Creek, with the hydrograph at 79,168 ft, at the confluence of Alligator Creek and Geronimo Creek. The peak flow values are nearly identical, but the broader hydrograph represents a much larger total volume of water the downstream location.

This sharp peak is very sensitive to detention and routing effects, and accounts for the high efficiency of upper reach ponds shown in Figure 5-4. Consequently, detention ponds in this upper region can have a strong localized effect. However, most of the benefit of ponds in this location will be localized as any modifications upstream of this reach have little effect on downstream flows. In contrast, downstream ponds must detain a much larger volume of water to attain the same peak flow reduction. However, it can be seen in Figure 5-3 that ponds within Geronimo Creek provide reduction which propagates consistently downstream.

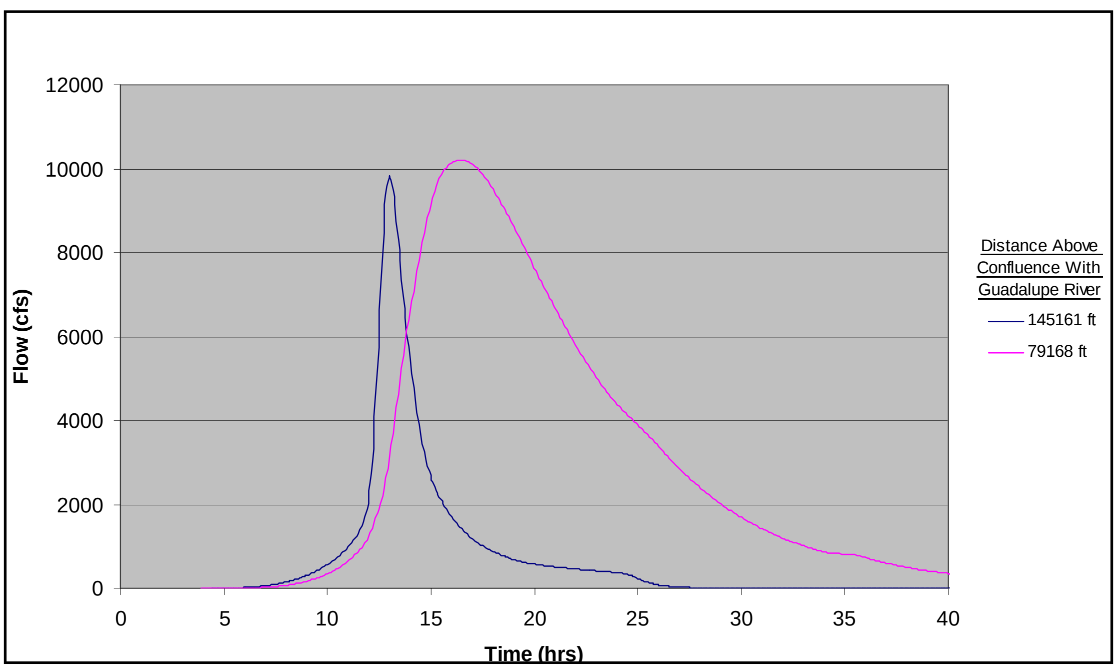


Figure 5-5: 25-Year (4% annual) Hydrograph Comparison

Using these two rules of thumb, a planner can get a quick estimate of the scale of project involved in achieving any desired floodplain reduction. It can also be seen, however, that such projects are unlikely to be cost effective. For example, the seemingly modest goal of reducing the 100-year flood elevation by 2 feet requires approximately 8000 cfs reduction. At 1.5 cfs/acre-ft, this necessitates 5300 acre-ft of storage volume. If we assume pond depths of 15 feet, this equates to over 350 acres of land.

## 5.5 Regional Detention Regulations

Currently all four regulatory authorities for the Geronimo Creek watershed have detention requirements as part of development regulations. Comal County, Guadalupe County, and the City of New Braunfels require detention for the 1% annual storm event. The City of Seguin requires detention of the 50%, 20%, 10%, 4%, 2%, and 1% annual storm events for all new development.

More stringent detention requirements in the upper portions of the watershed will have significant impacts on flooding for lower intensity more frequent storms, which in this watershed have the potential for structural damage and loss of life due to roadway flooding. Inversely, the detention requirements in the lower Geronimo Creek watershed, specifically southern Guadalupe County and the City of Seguin, should be evaluated on a case by case basis to determine if detention is beneficial or detrimental to the timing of downstream flood water peaks.

Future regulations will not reduce the occurrence or magnitude of current flooding. However, increased design criteria for detention ponds may reduce the rate at which flooding increases due to development in the watershed.

## 5.6 Flood Early Warning System

The primary objective of early warning systems is to notify local officials, emergency services, and the general public in flood prone areas of imminent danger in order to assist with the organization and implementation of evacuations. Early warning systems can prevent loss of life and property during a flood event if the information is distributed in a timely and accurate manner.

Residents in the lower reaches of the Geronimo Creek would benefit greatly if a system were in place that notified them of intense rain, increasing flow rates, or rising water in the upper portions of the Alligator and Geronimo Creek watersheds. This would allow for more effective and timely evacuations and the removal of portable property from flooding risk.

Automatic gates at stream crossings could significantly reduce the possible loss of life. The gates can be integrated with the flood warning system and designed to close the road during flood events. Additional benefits would be in the form of reduced man hours for County/City road crews setting up and removing barricades at flooded crossings; and reduced risk for emergency services responding to flood related rescues at stream crossings.

## 5.7 Buyouts for Repetitive Loss Structures

Removing structures and relocating residents from the floodplain is the most effective means of reducing flood damages and potential loss of life and property. Buyouts were evaluated for the Elmwood Subdivision in the City of Seguin. Elmwood is located adjacent to Geronimo Creek and is subject to repetitive flooding. Numerous insurance claims are filed by residents in this neighborhood after major flood events ranging from during the time frame of 1981 to 2007. The claims for this area can be see in Table 5-1 below.

Table 5-1: Elmwood Annual Flood Insurance Totals

| Year | Claims | |
|---|---|---|
| 1981 | $ | 321,192 |
| 1983 | $ | 967 |
| 1998 | $ | 1,702,950 |
| 2002 | $ | 336,521 |
| 2004 | $ | 2,310,718 |
| 2007 | $ | 155,796 |
| **Total** | **$** | **4,828,144** |

The cost to purchase the 33 homes in the proposed 1% annual floodplain in Elmwood would be $4,599,124 (based on appraisal district values). This value does not include costs for relocation. The benefit-cost ratio solely based on the total insurance claims paid to date is 1.05. It is evident that major flood events have become more frequent since 1998, which is cause to believe that the buyout costs could possibly be recovered (by eliminating claims) in 10-15 years.

# 6.0 RECOMMENDATIONS

Based on the evaluation of the four structural alternatives it was concluded that regional detention ponds are the only mitigation option that shows beneficial impact to flood elevations. Due to the characteristics and sensitivities of the watershed, very large ponds are required to yield beneficial impacts. Relationships were discovered that would allow municipal planners to estimate the scale of a detention project involved in achieving desired floodplain reduction.

Although the benefit-cost ratio for a regional type of detention structure appears to be skewed toward being unfavorable, it is important to note that this ratio is based upon existing conditions. Obviously, it is impossible to accurately predict future basin development, but as the basin does develop, the benefit-cost ratio should improve as additional structures and improvements have the potential of having limited impact from a flood event by flood waters being detained by the regional detention pond. This study evaluated only the traditional, financially-based, benefit-cost ratio. Recently there has been a national trend to quantify, not only the traditional, financial benefit-cost ratios, but also consider other benefits such as environmental and social. This new benefit-cost analysis is called the Triple Bottom Line (TBL) and includes quantifying the financial, social, and environmental benefits. It may be prudent to perform a TBL on a regional detention structure to further show the benefits of this proposed solution.

Due to the magnitude of detention volume required to have significant impacts on the floodplain no one detention pond can reasonable be expected to be constructed in this watershed. Instead a two pond scenario is recommended. Pond 1 is proposed to be located immediately downstream of the confluence of Alligator and Geronimo Creeks. This area is prone to flooding and has been identified by residents as a re-occurring problem. The pond is approximately 225 acres in surface area and 2,250 acre-feet of detention volume. The large size of this pond could easily lend itself for use as a park facility with ball fields, play grounds, hiking trails, etc. located within the inundation area.

Pond 2 is located north of Laubach Road on the Geronimo Creek near Haberle and Willmann Roads. This location was chosen based on available undeveloped property, favorable topography, and ideal opportunity for inflow and outflow structures adjacent to the stream. The pond is approximately 75 acres in surface area and 750 acre-feet of detention volume.

The water surface elevation reduction for the 1% Annual event as a result of the two ponds ranges from 1.0 to 1.6 feet. The probable construction costs for Ponds 1 and 2 are approximately $18.9 Million and $6.3 Million respectively. Costs used to estimate detention ponds were based upon City of San Antonio 2009 average bid pricing. If local participation includes using local resources, equipment, and labor, the cost of large detention ponds has the potential of being greatly reduced, thereby improving the benefit-cost ratio. See Appendix A, Exhibit 9 for a preliminary location of the proposed ponds.

In addition to desirable affects for the 1% Annual event, the ponds also lower water surface elevations for the 10% and 4% events (10- and 25-year). These events result in less total rainfall and intensity, but are more frequent in return period. Therefore, by reducing flood depths during these events benefits can been seen more frequently occurring.

As the ultimate goal of reducing flood damage is shown to be achieved through peak flow reduction by detention ponds, a flood planning and regulatory approach also shows promise for mitigating future flood damage or loss of life. Options for this approach include the creation of regional detention regulations to minimize future growth of the floodplain, increasing restrictions for construction within the 1% Annual floodplain, and the installation of physical measures such as flood warning systems and automatic gates at crossings. Buyouts and relocation of repetitive loss structures was proven to be a cost-beneficial alternative to reduce the flood damage in the Elmwood subdivision in Seguin.

# 7.0 IMPLEMENTATION AND FUNDING

The recommended detention alternatives as outlined in this study total over $25,000,000 in probable construction costs. This is beyond the capacity of the County's operational budget and implementation will require additional funding from various sources. Generally, Guadalupe County has the following potential sources available for accomplishing recommended flood protection measures:

- Annual Operating Budget
- Developer Contribution
- Establishing a Regional Stormwater Program and collecting Impact Fees
- Taxes
- Bonds/Debt Instruments
- State Programs:
    - <u>TWDB Clean Water State Revolving Fund –</u> Provides low interest loans for the planning, acquisition, and construction of stormwater and nonpoint source pollution control.
    - <u>TWDB Texas Water Development Fund –</u> Provides loans for the planning, acquisition, and construction of stormwater and nonpoint source pollution control, reservoirs, and flood control structures.
- Federal Programs:
    - <u>FEMA Flood Mitigation Assistance Program (FMA) –</u> Provides grants for planning assistance to communities in implementing measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insurable under the National Flood Insurance Program (NFIP). Eligible work includes: Acquisition of insured structures and real property; Relocation or demolition of insured structures; Dry flood proofing of insured structures; Elevation of insured structures; Minor, localized structural projects that are not fundable by State or other Federal programs; and Beach nourishment activities such as planting of dune grass.
    - <u>FEMA Hazard Mitigation Grant Program (HMGP) -</u> Provides grants to States and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster.
    - <u>FEMA Pre-Disaster Mitigation Grant Program (PDM) -</u> Provides funds to states, territories, Indian tribal governments, communities, and universities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event.
    - <u>FEMA Repetitive Flood Claims Program (RFC) -</u> Up to $10 million is available annually for FEMA to provide RFC funds to assist States and communities reduce flood damages to insured properties that have had one or more claims to the NFIP. FEMA may contribute up to 100 percent of the total amount approved under the RFC grant award to implement approved activities, if the Applicant has demonstrated that the proposed activities can not be funded under the Flood Mitigation Assistance (FMA) program.

- FEMA Severe Repetitive Loss Program (SRL) - Provides funding to reduce or eliminate the long-term risk of flood damage to severe repetitive loss (SRL) structures insured under the NFIP.
- Natural Resources Conservation Service (NRCS) Emergency Watershed Protection - Program objective is to assist sponsors and individuals in implementing emergency measures to relieve imminent hazards to life and property created by a natural disaster. Activities include providing financial and technical assistance to remove debris from streams, protect destabilized streambanks, establish cover on critically eroding lands, repairing conservation practices, and the purchase of flood plain easements. The program is designed for installation of recovery measures.
- NRCS Watershed Protection and Flood Prevention Operations - Watershed Operations assistance may be provided in authorized watershed projects to install conservation practices and project measures (works of improvement) throughout the watershed project area. The planned works of improvement are described in watershed project plans and are normally scheduled to be installed over multiple years. Works of improvement may include floodwater retarding dams and reservoirs.

The projects identified through the study are eligible to be funded with the means listed above and potentially in conjunction with other jurisdictions/participants who would gain from the flood protection measures.

APPENDIX A
EXHIBITS

APPENDIX B
PONDPACK OUTPUT REPORT

APPENDIX C
HEC-RAS OUTPUT REPORT

APPENDIX D
FEMA BACKUP DATA (EFFECTIVE 1% ANNUAL)

APPENDIX E
STREAM CROSSING RANKING: CRITERIA SCORING PARAMETERS

APPENDIX F
TWDB COMMENTS AND RESPONSE