2015

Duncan, Arizona Levee Proposal

NAU CROWN ENG

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1.0 Project Understanding

This project focuses on reducing the flood risk in Duncan, Arizona by implementing a new levee system along the Gila River. To assure complete understanding of the project, the following areas were investigated: project purpose, background, technical considerations, potential challenges, and the stakeholders who are involved.

1.1 Project Purpose

In a report performed by the Federal Emergency Management Agency (FEMA), the current levee in Duncan, along the Gila River, is rated to have no effect against 100-year floods [1]. Since most of the Duncan community is situated in or near the floodplain, residents are highly prone to costly flood damage. The goal of this project is to design a new levee system to ensure that citizens of Duncan are better protected against future floods.

1.2 Project Background

Duncan is an agricultural-based town of approximately 800 residents, most of whom live along the Gila River [2]. The town is situated in southeast Arizona, near the New Mexico border, and is part of Greenlee County (*refer to Figures 1.1 and 1.2 for location*). The town was erected in the 1870's as a result of the mining industry in Clifton and Morenci, which are nearby towns in northern Greenlee County. To help distribute ore from the mines, a rail line was developed from Clifton to Lordsburg, New Mexico. This rail line passed through Duncan, which became noticed for its naturally irrigated lands along the Gila River [2]. With its fertile lands, a prosperous mining industry, and a railway for travel, Duncan quickly became an attractive location for farmers and ranchers.

Figure 1.1 *-Location of Duncan in respect to the southwest portion of North America [3].*

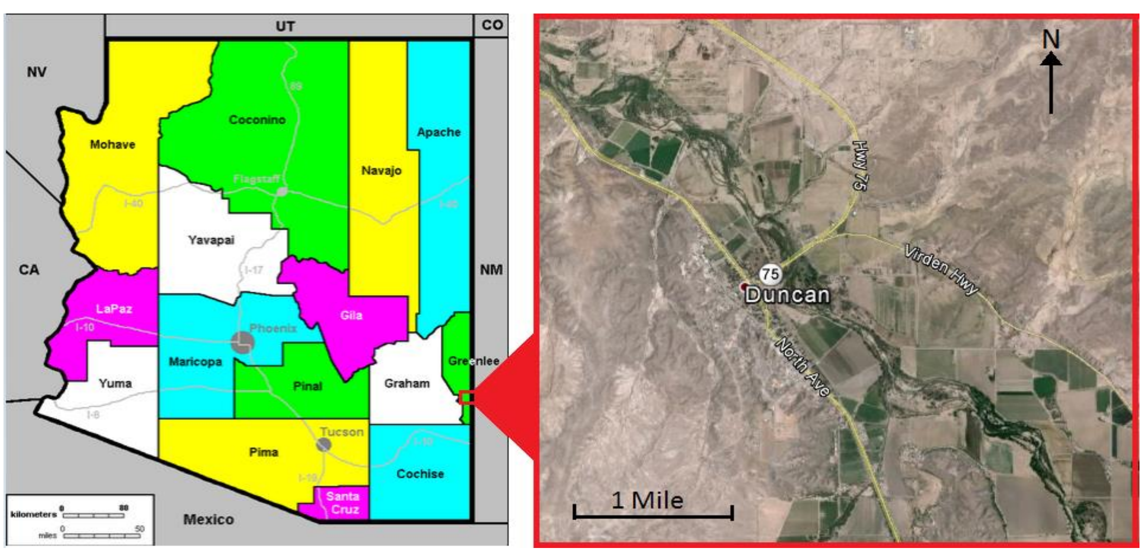

Figure 1.2 *- Location of Duncan and its county with respect to Arizona [3], [4].*

Figure 1.3 - *Location of current levee in Duncan. The yellow line running along the west side of the river exhibits the current levee in place [6].*

Ever since its establishment, Duncan has relied on the Gila River to fuel its primary industry of agriculture. While the Gila River is a vital resource for the town, it is also the cause of flooding within the community. To combat this flooding, a dirt-based levee was built along the river banks to help contain the waters of the Gila River. Like most rural areas that are subject to flooding in the United States, the levees of Duncan were most likely constructed by local farmers during the town's origins in the late 19th century [5]. The levee of interest spans approximately one mile and is shown in Figure 1.3 as the yellow line [6].

While the current levee is effective for minor floods, it is incapable of withstanding conditions beyond 10-year flooding events. The levee lacks sufficient engineering and has been breached multiple times throughout Duncan's history. The worst flood on record occurred in December of 1978 when the Gila River reached a flow of nearly 60,000 cubic feet per second (cfs) [6]. The 1978 flood severely damaged local infrastructure and brought siltation and erosion damage to the agricultural properties. The total damage of the flood was estimated to over 9 million dollars (Adjusted to the 2015 dollar) [7]. Figures 1.4 and 1.5 depict the conditions of Duncan during large-scale floods. To prevent flooding disasters, FEMA recommends levees to be designed for 100-year floods at the least. At the State Highway 75 Bridge in Duncan, the Gila River's 100 year flow is estimated to be 28,500 cfs [1]. This poses a problem since the current levee is estimated to receive considerable damage beyond 7,000 cfs and potential failure at 20,000 cfs [8]. As stated in a 2007 report by FEMA, "the levees have no effect on 100 and 500-year floods" [1] . Since the levee is considered inadequate for 100-year flood events, FEMA does not recognize it when developing Flood Insurance Rate Maps (FIRM). As a result, much of the town is considered in high risk of flooding under base flood (100-year) conditions *(refer to Appendix A for FIRM)* [9]. To protect Duncan from future flooding disasters, the current levee system needs to be addressed and modified to conform to larger flooding conditions.

Figure 1.4-*Aeiral photo of the 1978 Duncan flood [6].*

Figure 1.5 -*Flood of Duncan properties in 2005 [6].*

1.3 Technical Considerations

Levee design and analysis requires technical work in the specific area and conformance to design standards. The technical considerations of this project include: geotechnical properties of the Duncan area, the hydraulics and hydrology of the Gila River, sedimentation build up within the river, regulatory framework, and levee certification guidelines.

1.3.1 Geotechnical Properties of Duncan

Most levees along river banks are made of compacted soils-as is the case in Duncan. While soils are capable of containing floodwaters, the type of soil may lead a levee to be subject to erosion, seepage, and structural failure. To determine the soils along the Gila River, a soil map survey was investigated using data from the United States Department of Agriculture [10]. The area surveyed can be found in Figure 1.6, while the important properties of the soil can be found in Table 1.1. As seen in Table 1.1, the K-Factor, hydraulic conductivity and abundance of each soil type are listed.

***Table 1.1**-Soils found in Duncan. The number assigned to each soil corresponds to the soils location in Figure 1.6*

Type of soil	K-Factor Rating	Hydraulic Conductivity (in./hr.)	% of area of interest
15:Glendale silty clay loam, 0 to 2 percent slopes	0.43	0.06 to 0.20	10.7%
16:Glendale-Gila complex, 0-5% slopes	0.43	0.20 to 0.57	5.0%
27:Pima silty clay loam, 0-2% slopes	0.43	0.06 to 0.20	57.4%
17:Torrifluvents-Riverwash complex, 1-5% slopes	N/A	0.20 to 0.57	27.0%
Total for Area of Interest			100%

The K-Factor reflects the susceptibility of a soil to sheet and rill erosion by water. It is one of the six factors that are used in the Universal Soil Loss Equation and its revised version is used to predict the annual average rate of soil loss by sheet and rill erosion in tons per acre per year. The values of the K-Factor range from 0.02 to 0.69 [10]. Low values indicate less susceptibility to detachment or erosion, while high values indicate more susceptibility to detachment or erosion. Another important property is the hydraulic conductivity, which can be represented by "k". The hydraulic conductivity describes the rate at which a fluid, typically water, can move through a solid.

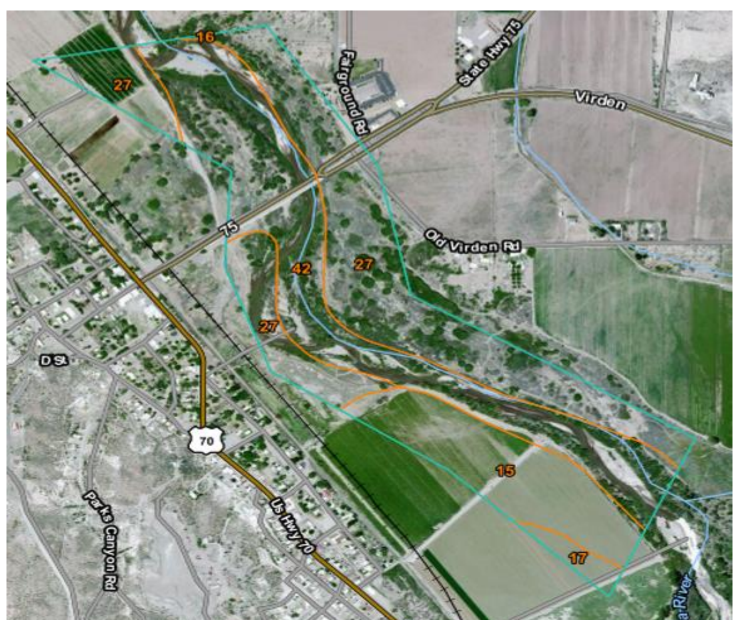

***Figure 1.6**- Map of Soils in Duncan [10]*

In designing a levee, the K-Factor and hydraulic conductivity are essential to know since seepage and erosion failures are a common occurrence. Other technical aspects of the soil such as its shear strength, water limit, and plastic limit should also be considered, however, these will require field soil tests.

1.3.2 The Gila River

In the design of a levee, the hydrology and hydraulics of the river must be understood to determine the size and strength of a correctly designed levee. Information gathered from the river should feature flow rates and cross sections so that a levee design can be evaluated through the Hydrologic Engineering Centers River Analysis System (HEC-RAS) software [11].

Figure 1.7-Gila River Drainage Map [12].

As seen in Figure 1.7, the Gila River spans nearly 600 miles in its westward journey from New Mexico to the Colorado River. With all of its tributaries, the Gila River accounts for approximately 60,000 square miles of drainage [12]. The portion of drainage that occurs around Duncan is part of the Upper Gila River Watershed, which is responsible for draining over 15,000 square miles of land *(Refer to Appendix B for watershed map)* [13]. Of that area, the Gila River is estimated to drain approximately 3200 square miles upstream of Duncan [1]. Flow conditions of the Gila River are typically 300 cfs [8], however, the 100 year storm has been estimated to flow at 28,500 cfs [1]. The discharge will range depending on weather conditions. The Gila River's discharge is categorized into a winter flow and summer flow. During the winter frontal storms, snowmelt, and/or groundwater storage outflow will contribute to flooding. In the summer season, tropical storms are known to cause the largest risk of flooding since these storms can release precipitation at rapid rates [1]. Figure 1.8 provides insight to the precipitation and temperature patterns of the Duncan area. For more information on the hydraulics of the Gila River, *refer to Appendix A.*

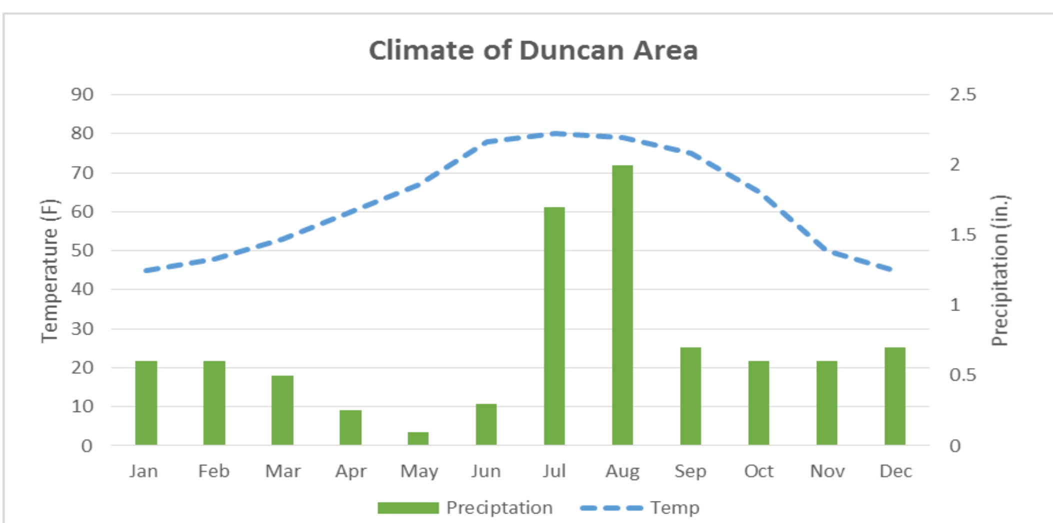

Figure 1.8-Precipitation and Temperature of the Duncan Area. [12].

1.3.3 Sedimentation

Sedimentation occurs when sediment is deposited in or along a body of water. This could potentially cause problems with respect to a levee. Levees need to be a certain height above the river in order to become certified and accredited. If too much sediment builds up, the river bed will sit at a higher elevation. This will cause the change in elevation between the levee crown and the free surface of the river to decrease. If enough time passes, this could cause a certified levee to be decertified.

1.3.4 Regulatory Framework

It is important for many government agencies, including FEMA, to ensure the safety of citizens and their area by making them aware of the risk that is associated with living behind a levee. To reduce this risk, it is necessary to have proper regulatory framework for designing and constructing levees [14].

Before constructing a levee, the design must be certified by a professional engineer or a federal agency that designs levees. For levee accreditation, appropriate documentation and data must be provided to land owners, communities, etc. The levees are accredited based on the following areas:

1. General Criteria:

For FEMA recognition, levees must meet the minimum standards of consistency with the protection level found in 44 CFR Section 60.3 and the comprehensive floodplain management criteria [14].

2. Design Criteria:

The criteria for structural design demonstrated in data and documentation of levees is need for certification by a registered professional engineer. The documentation submitted should include certified as built plans, recent pictures of levees, and levee and embankments closures. This documentation will help FEMA in reviewing the levee.

The information that is necessary in reviewing a levee for FEMA is as follows [14]:

- It should include the design of freeboard, including coastal and riverine levees
- It should include the designs for closures, which will show all the opening having closure devices.
- It should include data for protection of embankment, showing that there will be no erosion of levee embankment in the base flood.
- Stability analysis for embankment and foundation, which evaluates expected seepage, including duration, penetrations, flooding depth, and other stability factors under the condition of base flood loading.
- Analysis of settlement, which shows that the minimum freeboard is maintained and assesses the freeboard loss in settlement.
- Analysis of internal drainage performed by a professional engineer who identifies the source and magnitude of interior flooding.
- Additional design criteria for ensuring risk reduction for the levee.

3. Operations and Maintenance Plans and Criteria:

The information which fulfills the minimum standard requirements of 44 CFR 65.10(C) and 44 CFR 65.10 (D) is included in the operations and Maintenance plans and criteria. The jurisdiction of Operation and Maintenance Plans comes under a licensed agency and must be adopted officially by that agency, by getting a vote from a body who is governing [14].

1.3.5 Environmental Protection Agency

Since the Gila River is an open water source and a navigable water, it is protected by the Environmental Protection Agency under the Clean Water Act [15]. Being a comprehensive legislation on water conservation and minimum ecological implications, the Clean Water Act provides provisions to regulate the discharge of contaminated and fill water into waterways and wetlands. Various development projects such as dams and levees, under Section 404 of the act, require permission from designated departments before the dredged or fill material may be discharged into waterways or over wetlands.

It is typically the duty of the U.S. Army Corps of Engineers to enforce Section 404 of the Clean Water Act and to oversee its respective permits. The permit process is required to be completed prior to the construction of a levee along a river. Every project needs to be evaluated for its positive benefits for the public and its potential implications over the habitat and ecological system before a permit may be granted. CWA Section 404(b) (1) Guidelines are the most significant part of the legislation in this regard, along with regulations as adopted by the Environmental Protection Agency (EPA). The Corps issues general permits for nationwide activities of corporations working across the country. These kinds of permits are exempted from specific studies required under individual reviews, thus facilitating businesses across the country to conduct their activities without losing time and money [15].

1.3.6 Endangered Species Act

Before starting the construction of levee, it is important to consider the effect it will have on species listed or proposed as threatened or endangered species. The endangered species can be affected in many ways including individual effect or habitat effect. To reduce the impact of any construction on endangered species' habitats, the Endangered Species Act was passed in 1973, to protect endangered and threatened species. This law is enforced by the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Services (NMFS). These agencies identify and perform actions to protect the species and their critical habitats.

The ESA is not a part of an EPA requirement, but due to its great importance, it is included in the EPA Stormwater Construction General Permit (CGP) requirements. It has different requirements for activities related to federal and non-federal agencies. It is generally applied to the construction activities in three general scenarios [16]:

1. Activities of construction under EPA'S CGP.
2. Activities for a construction project for which funding is provided by federal agencies.
3. Construction activities that have a major impact on listed endangered species and their critical habitat.

1.3.7 Certification

The definition of certification written in 44 CFR 65.2 (b) states that "it is a statement which authorizes that the information submitted is accurate and in accordance with sound engineering practices" [14].

Levee certification is the process dealing with the physical condition and design of a levee. It is a necessary step in making a levee eligible for accreditation by FEMA. After submitting all of the data complying with the requirement based structural principles outlined in steps 1-3 above, it must be certified by a registered professional engineer along with the levee's certified as-built. The documentation submitted must include:

- The levee meeting the requirement standards of 44 CFR, Section 65.10
- The authorization for the accuracy of data
- Stating that the tests and analyses performed are accurate and consistent with sound engineering practices.

How the levee is certified: The community or owner should work with a registered professional engineer or federal agency to certify and develop all of the documents stating that the levee meets construction standards set for an annual flood chance of 1% or less [17].

1.3.8 Right of Way

In order for a levee system to be implemented, it must receive a development permit and occupancy permit by the county engineer and zoning inspector [18], [19]. To receive these permits and achieve the right of way status, the development must be decided as an appropriate use of the land. In the case of a levee, its use of land can be justified under Sec. 314c of the Greenlee County Zoning Regulations. Under this condition, land may be used for "essential services of other public agencies such as drainage, flood control, irrigation, fire and sanitary districts and including facilities, attendant appurtenances and accessories used by such agencies" [19]. While the levee can be justified, there may be challenges if the levee crosses over any private properties. In this event negotiations will have to be made with the property owner.

1.4 Potential Challenges

The greatest potential challenge of this project is the availability of existing data. NAU Crown Engineering intends to collect geotechnical information, survey data, and Gila River hydraulics and hydrology information through previous studies. If no data are available, field studies will be performed. In this case, the schedule will be revised.

1.5 Stakeholders

The implementation of a new levee system along the Gila River will directly affect a wide range of people due to its proximity to the community and the river. Table 1.2 lists all stakeholders who would be involved with the project.

Table 1.2-Stakeholders of Levee Project in Duncan

Stakeholder	Role
USACE	Since the Army Corps of Engineers is in charge of all navigable waterways in the United States, they will have the final decision in whether or not the construction of a new levee will be allowed.
Greenlee County Government	The Greenlee County government will need to find the resources to fund the construction of a new levee. The county's engineer will also need to be involved in the permitting processes for constructing and certifying the levee.
Property Owners in the Floodplain	The property owners who live in the floodplain will benefit from the construction of a certified, accredited levee. These people will no longer need to pay for flood protection because FEMA will redraw the floodplain map with the levee in place.
Agriculture	The people in Duncan who have an agriculture-based business will not need to worry about a flood wiping out their livelihood.
FEMA	After the levee has been certified by a qualified practicing engineer, FEMA will be in charge of the accreditation of the levee and reassessing the floodplain.
Environmentalists	The presence of threatened and endangered species in this area makes it necessary for certain acts, such as the Endangered Species Act, to be followed during the construction of the levee.

2.0 Scope of Services

Upon approval, NAU Crown Engineering will provide the following services for Greenlee County and their levee in Duncan, Arizona:

Task 1 Data Collection

NAU Crown Engineering will need to acquire technical data related to the project site in Duncan. Data of interest includes: geotechnical properties of Duncan, hydraulics and hydrology of the Gila River, and survey reports specific to the area around the Duncan Levee.

Task 1.1 Geotechnical Assessment

Since levees are commonly composed of soils, it is important to know what type of soils are available in the area to determine if they could be used for construction of the levee. Knowing the soil type and its properties will impact the design of the levee. An ideal soil will have low seepage rates and high cohesive strength. To determine geotechnical information of the area, soil data will be taken from reports conducted by the Natural

Resources Conservation Service. If any pertinent soil data is unavailable, NAU Crown Engineering will collect soil samples from the site and conduct testing.

Task 1.2 Gila River Hydraulics and Hydrology Data

The depth and flow of the Gila River will set the parameters for the new levee design. Levees are to be designed to accommodate 100-year floods to receive FEMA accreditation. NAU Crown Engineering will research historical data and storm hydrographs, specific to Duncan that will be used to find the 100-year flood conditions. If sufficient data is unavailable, hydrological analysis will be performed on the watershed above Duncan.

Task 1.3 Survey Data

For modeling and design purposes, survey data of the Duncan area will be required. Ideally, this information will be provided by the client. If it is not, this data will be gathered from the Bureau of Reclamation. If any of the obtained data is insufficient or outdated, NAU Crown Engineering will conduct a field visit to collect necessary survey points.

Task 2 Site Assessment

NAU Crown Engineering will visit the site to assess the current levee and any other conditions that may hinder the design options.

Task 2.1 Levee Assessment

Previously gathered data and HEC-RAS software will be used to assess the current levee system. The HEC-RAS software offers the option for identification of levees at each cross section. Through the software, the flow at which the levee is overtopped, or breached, can be determined along the entire levee system. The purpose of running this simulation is to find the flaws in the current levee design and determine corrective actions so that the levee can withstand 100-year flood conditions.

Task 2.2 Endangered Species Assessment

In order to construct a levee system, all parameters set by the Endangered Species Act of 1973 (ESA) must be followed. Furthermore, any project will need to be worked in coordination with the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Services (NMFS) who are responsible for enforcing the ESA. These departments will identify species at risk in the area and provide permit actions in how to develop along a critical habitat [16].

Task 3 Design of New Levee

The final levee design, including dimensions as well as materials and quantities, will be accomplished using the information provided from Tasks 1 and 2. This design will be sketched using AutoCAD or Civil 3D software. The design will show various cross sections, along with complete plan and profile views.

Task 3.1 Civil 3D Modeling

The levee will be designed using Civil 3D software and will follow guidelines set by the FEMA approach. This entails a levee design that will be able to accommodate 100-year flooding events. In accordance with FEMA guidelines, the height of the levee must feature at least 3 feet of freeboard during 100-year flood conditions [20].

Task 3.2 Test Design Model with HEC-RAS

Once a new levee design is complete, it will be tested for functionality using HEC-RAS. The new design parameters of the levee will be inserted to HEC-RAS to determine whether the new levee offers optimal dimensions against 100 year flooding events. Design modifications will be performed until NAU Crown Engineering is satisfied with the HEC-RAS simulation.

Task 4 Project Management

An ongoing task will be to maintain contact with the client and to ensure that all deliverables and services are provided for in the set time frame.

Task 4.1 Client Contact

The client for the proposed levee project in Duncan is Phil Ronnerud, who is the Greenlee County Engineer. NAU Crown Engineering provides contact to the client through Charlie Wilson, an undergraduate student working on the project, and Dr. Charles Schlinger, who is the technical advisor of the project.

Task 4.2 Deliverables

NAU Crown Engineering will provide the following deliverables to the client between the months of August and December of 2015:

- A 50% design report will be submitted on November 10th.
- A formal presentation over the levee design will be held on December 10th at Northern Arizona University. The presentation will be 20 minutes long with 5 minutes for questions.
- A website that fully exhibits the project will be operational by August and frequently updated; completion will be by December 18th.
- A final levee design report will be submitted on December 18th.

2.1 Exclusions

NAU Crown Engineering will abide by the declared scope of services. However, some services that may be valuable to a complete project will not be provided. These services, which are known as exclusions, are provided in the following list.

- NAU Crown Engineering will design the levee to meet the requirements of FEMA, but will not take part in the certification process.
- Although the most heavily populated area of Duncan will be protected from flooding by the levee, portions of the town will be left vulnerable to the floods. The area of focus is shown in Figure 1.3.

- Land approvals will be needed in order to construct the levee, but the duty of attaining the approvals will be left to Greenlee County officials.
- The final design will be submitted to the client, who will be accountable for acquiring approval of construction from the US Army Corps of Engineers.

3.0 Schedule

Figure 3.1 exhibits the timeline that NAU Crown Engineering plans to follow for the duration of the levee design project in Duncan, Arizona. The schedule is based on the scope of services that are to be provided to the client. The project will begin on September 1st, 2015 by initiating data collection pertinent to the levee design. As indicated by the critical path in the figure (black arrow), all data collection will need to be complete in order to run a HEC-RAS model of the current levee in place. While the project site is being investigated, Task 3 can begin, which features designing the new levee. Once the design is complete, NAU Crown Engineering will be able to proceed to a formal design paper and presentation. From the start to finish of the project, the task of project management will be ongoing. When 50% of the project is complete, a report will be submitted to the client. In addition, a project website will be developed to show the progress and design details. Upon completion, a final presentation will be given on December 10th, 2015 and a final design report will be submitted on December 18th, 2015.

Duncan, AZ Levee Desgin Schedule for 2015

ACTIVITY	Begin Date	End Date
Task 1 Data Collection	1-Sep	14-Oct
1.1 Geotechnical Assessment	1-Sep	6-Oct
1.2 Gila River Hydraulics/Hydrology	3-Sep	13-Oct
1.3 Surveying	3-Sep	14-Oct
Task 2 Site Assessment	15-Oct	6-Nov
2.1 Levee Assessment	15-Oct	6-Nov
2.2 Endangered Species Assessment	15-Oct	6-Nov
Task 3 Design of New Levee	28-Oct	9-Dec
3.1 Civil 3D Modeling	28-Oct	9-Dec
3.2 HEC-RAS Testing	10-Nov	9-Dec
Task 4 Project Management	1-Sep	18-Dec
4.1 Client Contact	1-Sep	18-Dec
4.2 Deliverables		
50% Design Report	10-Nov	
Presentation	10-Dec	
Final Design Report	18-Dec	

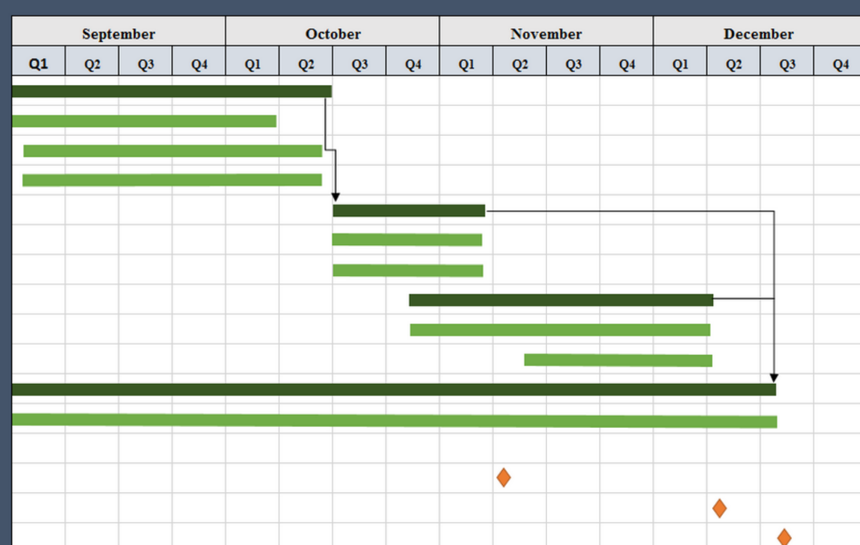

__Figure 3.1-__ Gantt chart for Levee Design Project

4.0 Staffing and Cost of Engineering Services

NAU Crown Engineering will devote one senior engineer (SENG), one professional engineer (PE), and one engineer in training (EIT) to complete the project. Table 4.1 provides the allotted time that each position will require. Table 4.2 displays the personnel and travel costs associated with the entire project based on the hours allotted from Table 4.1. In total, the estimated cost of engineering services for the levee design project is $56,792.

***Table 4.1**-Staffing Plan*

Task	Classification	Required Hours
Task 1 Data Collection		
Survey data	EIT	40
Geotechnical Data	EIT	56
Hydraulics and Hydrology Data	EIT	56
Task 2 Site Assessment		
Examining Site	ENG	96
	SENG	32
HEC-RAS Simulation	ENG	64
Coordination with Endangered Species Act	SENG	48
Task 3 Design of New Levee		
Civil 3D Modeling	ENG	120
HEC-RAS Testing	ENG	48
Task 4 Project Management		
Public and Client Contact	SENG	48
Total		**608**

***Table 4.2**-Cost of Engineering Services*

Classification	Hours	rate ($/hr)	Cost
SENG	128	$130	$16,640
ENG	328	$90	$29,520
EIT	152	$60	$9,120
Travel (2 meetings)			
700 miles/meeting	$0.40/mi	700 Miles	$560
Hotel		$70/night x 2 room	280
Vehicle Rental	2 Days	$40/day	$160
Per diem	2 days x 4 people	$32/day	512
Total Travel			$1,512
Total			**$56,792**

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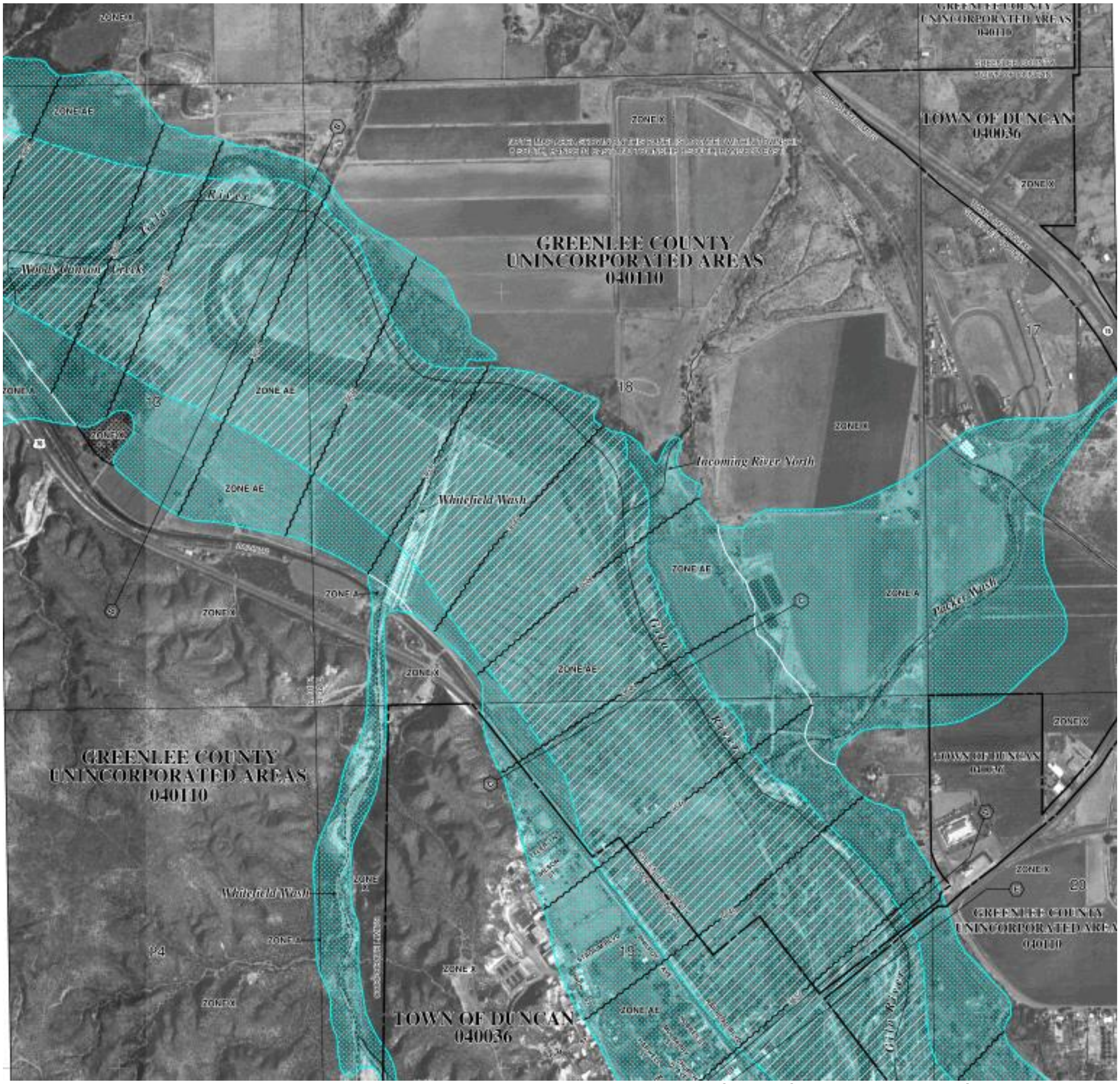
6.0 Appendices

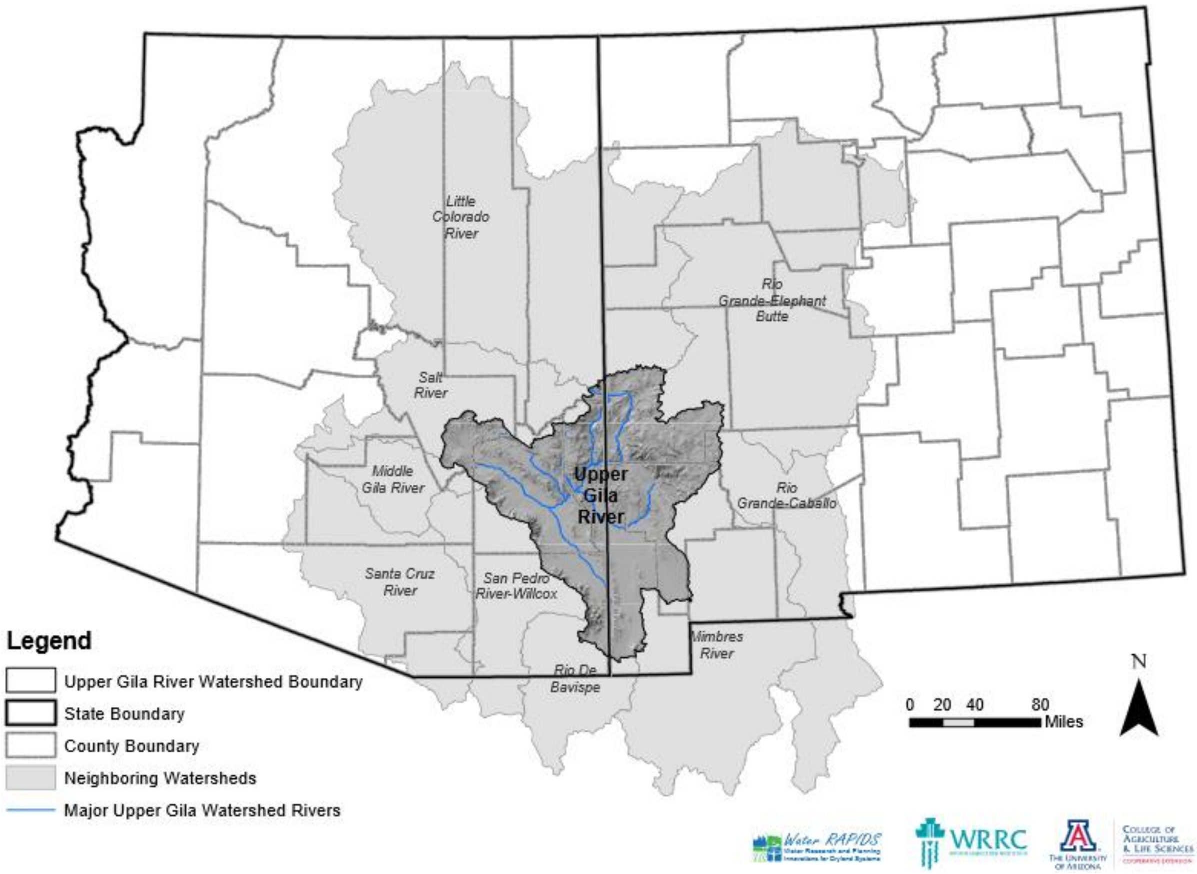
Appendix A-Maps and Gila River Data

FEMA Flood Insurance Rate Map of Duncan [9]**.**



-Areas in blue, surrounding the Gila River, show projections of how far the 100-year flood will spread. This information is used by FEMA's National Flood Insurance Program to assess flood risk for insurance companies. If a certified levee were in place, the flood risk of Duncan would decrease and insurance rates would lower.

Upper Gila River Watershed [13].



Gila River Properties [13]**.**

Stream	Left Overbank "n"	Channel "n"	Right Overbank "n"
Chase Creek	0.035 – 0.060	0.035 – 0.040	0.035 – 0.060
Gila River	0.014 – 0.107	0.014 – 0.107	0.014 – 0.107
San Francisco River	0.030 – 0.060	0.025 – 0.035	0.030 – 0.060

		Peak Discharges (cfs)			
Flooding Source and Location	Drainage Area (sq. mi.)	10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
Gila River					
At State Highway 75	3,200	13,700	23,800	28,500	42,500