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Development of a Cyberinfrastructure for Assessment of the Lower Rio Grande Valley North and Central Watersheds Characteristics

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DEVELOPMENT OF A CYBERINFRASTRUCTURE FOR ASSESSMENT OF THE LOWER RIO GRANDE VALLEY NORTH AND CENTRAL WATERSHEDS CHARACTERISTICS

A Thesis

by

LINDA ISABEL NAVARRO NAVARRO

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DEVELOPMENT OF A CYBERINFRASTRUCTURE FOR ASSESSMENT OF THE LOWER RIO GRANDE VALLEY NORTH AND CENTRAL WATERSHEDS CHARACTERISTICS

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ABSTRACT

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Due to an increase in urbanization in the Lower Rio Grande Valley (LRGV), there have been substantial modifications to hydrology causing a decline in water quality to the Laguna Madre watershed. The major concern is the inflow of freshwater from the North and Central waterways released to the Lower Laguna Madre which is designated as an impaired watershed for high concentrations of bacteria and low dissolved oxygen. The objective of this study is to perform a watershed characterization to determine potential pollution sources of each watershed by developing a cyberinfrastructure and collect a wide inventory of data. The objective will be achieved through the development of a Geographic Information System (GIS) database that will help to comprehend the major characteristics of each area contributing to the watershed supported by the analysis of the data collected. The watershed delineation is crucial for this study since it will determine the boundaries for each watershed promoting the identification of contributing potential sources of contaminants. Hidalgo Willacy Main Drain (HWMD) and IBWC North Floodway watersheds were found to have higher contribution of water impairments for their significant levels of water quality parameters along with non-point and point sources. Therefore, this study has facilitated the characterization of watersheds to better address water impairments.

DEDICATION

This thesis is dedicated to all my family in Mexico and my close friends. A special dedication to my parents, Martin and Myrna Navarro, my sister, Ana P. Navarro, and Caetano for their absolute love and support without them this would not have been possible. Also, to my advisors. Overall, to God for allowing me to have this opportunity to help preserve a healthy environment in my community.

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CHAPTER I

INRODUCTION

Area of Concern

The Lower Rio Grande Valley (LRGV) region has undergone sudden hydrology changes due to an abrupt urbanization growth. This has shown a decline in water quality in the primary waterways of the region. The Laguna Madre is an estuarine wetland system along the Gulf of Mexico that receives freshwater from the LRGV (Hernandez & Uddameri, 2013). This watershed is known for its recreational activities and is currently threatened by the inflows of main drainage pathways which carry significant levels of contaminants. According to Texas Commission on Environmental Quality (TCEQ) 2020 integrated report, two water segments from Laguna Madre are considered impaired for high levels of bacteria and low dissolve oxygen (Creek, 2020). The North and Central waterways provide freshwater inflows along with other drainage canals to the Laguna Madre. Currently, these waterways have not been characterized before. Watershed characterization will enable proper identification of potential sources of pollution to help reduce water impairments to the Laguna Madre and preserve the ecosystem.

Cyberinfrastructure

One of the tools emergent for watershed characterization is the cyberinfrastructure that can assist in data collection and help stakeholders within watershed in their decision-making process. The cyberinfrastructure supports the process of accessing data via an extensive network and provide updated water quality data for further research.

The introduction of a cyberinfrastructure can provide an efficient data collection to well demonstrate the watershed characteristics. In one study Yu et al., (2021) observed that a cyberinfrastructure not only utilized a widespread of data, but also allows researchers to analyze large amounts of data over time at different locations. This platform offers a rapid generation of new relationships between a wide inventory of data. The cyberinfrastructure secures data and delivers interpreted information via a sequence of web services and portals in forms that are universally coherent by distinct stakeholders (Gutenson et al., 2020). Cyberinfrastructure serves as a center for a variety of data from distinct sources such as non-point and point source, and watershed delineation characteristics. This kind of data can encompass geospatial data as well as non-geospatial data such as water quality and flow data. The cyberinfrastructure along with the watershed delineation are crucial for the watershed characterization since it will help in the identification of sources of pollution data within the drainage area.

Watershed Delineation

An ample watershed delineation is key for a successful watershed characterization. A watershed delineation is developed by using elevation data and compute several elevation-based files that represent the overall drainage area as well as hydrological characteristics of a watershed (Terra, 2015). Each watershed can be divided into subwatersheds for more detailed drainage structure. Geographical Information systems (GIS) platform has facilitated the development of the hydrological analysis such as drainage areas based on elevation data. Strager et al., (2010) conducted a hydrological analysis with watershed GIS-based applications to assist both technical and non-technical users for decision-making. His study shows positive outcomes with respect to

GIS-applications for watershed management and water quality by providing a full overview of the watershed characteristics such as land cover.

Hydraulic and distributed hydrological modelling as well as water resource management commonly requires investigation of landscape and hydrological features such as terrain slope, drainage networks, drainage divides, and catchment boundaries (Vaze et al., 2010). Additionally, high resolution in data resources is important to obtain accurate results in watershed drainage areas (Amatya et al., 2013). When land slope is very flat and has few contours, it is challenging for the acquisition of topographic maps. Light Detection and Ranging (LIDAR) is a high resolution digital elevation models (DEM) which is an ideal source for the type of topography characterized in low elevation areas (Whitko, 2005). Although the terrain in the LRGV is flat, the complex hydrologic features makes the process difficult and challenging with even high-resolution DEM. A study focused on enhancing streamlines and watershed boundaries derived from a high-resolution DEM for future hydrologic modeling and flood forecasting. (Maidment et al., 2016).

To determine accurate stream networks, an effective method of eliminating pits or depressions is the stream burning algorithm. This algorithm often identifies river channels or lakes that are not recorded in the DEM, avoiding serious errors in the streaming (Li et al., 2019; Chen et al., 2012). A stream burning algorithm can enhance the replication of streams positions by using raster representation of a vector stream network to trench known hydrological features into a DEM resulting in a comprehensive watershed delineation (Y. Chen et al., 2012; Callow et al., 2007; Sanders, 1999). In addition, delineation of watersheds will not only serve to determine drainage boundaries but to distinguish existing sources of pollution such as non-point sources (NPS) and point sources (PS).

Potential sources of Pollution

Part of watershed characterization is to identify potential sources of pollution within the watershed. Pollutant sources had been divided into two different classifications: NPS and PS, with this, it becomes easier to study, analyze, understand, and propose actions to mitigate the pollutant load. NPS are difficult to be identified since they cannot be tracked and usually come from several land uses. The major contributor of NPS is stormwater runoff originated by rainfall (Mahmoud et al., 2020) and other forms of water flow through several different land uses ultimately discharging to lakes, canals, and coastal waters. This runoff carries significant levels of pollution caused by: fertilizers, oil, grease, sediments, bacteria, and nutrients (TCEQ, 2007). The stormwater runoff primarily comes from agricultural lands, residential areas, urban areas, construction sites, and livestock. NPS pollutants contained significant amount of nutrients such as total nitrogen (N) and total phosphorus (TP) (Shin et al., 2016). There has been increasing emphasis on tackling nonpoint sources from agricultural land for the presence of high nutrient contamination (Burt et al., 2011). Currently, urbanization has led to increased water transfers from agriculture to urban uses (Hernandez & Uddameri, 2013; Black&Veatch, 2016). These changes are altering the nature, location, and scope of wastewater loadings into the river. Urban runoff have shown negative results on water quality for high bacteria and low dissolved oxygen (DO) levels (Mahmoud et al., 2020). The most recent set of 303(d) reports indicated that more than 40 percent of all impaired waters were affected solely by nonpoint sources, while only 10 percent of impairments were caused by point source discharges alone (EPA, n.d.-b).

Unlike NPS, PS are usually identified because they come from only one source. Although is easier to identify theses sources, it still has become a problem to address the issues causing PS pollution in primary waterways. To establish the proper actions to reduce or stop the pollutant load into the waterbodies is necessary to identify where the pollutant is coming from. A pollutant source is concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment (USEPA, 2008). Point pollution source identification is a challenging task because of the uncertainties and nonlinearity in the transport process of pollutants (Boano et al., 2005). The typical way to identify a point source requires obtaining prior information of the pollution source, gain complex information about pollution such as incidents regarding flow simulation dimensions, the number of point sources involved, and the pollutant release process (Guozhen et al., 2016). Determining potential sources is the first step in acting towards reducing the effects of water quality problems.

Water Quality Problems

According to EPA, the summary of water quality assessments in the US recorded almost 70% of all rivers and streams as unassessed In Texas, 87.9% of all rivers and streams are unassessed (EPA, 2017) In United States 52.9 % of the assessed water bodies were considered impaired for high levels of *E. coli* and fecal coliform (EPA, 2017). In addition, fecal coliform bacteria and other pathogens present in stormwater discharges threaten public health and have been responsible for numerous beach closings in the region (Abrams, Robert, 2012). Some studies have found that both livestock and manure management can potentially be agricultural sources of fecal indicator bacteria in watersheds (UWRRC, 2014). Moreover, estuaries have faced eutrophication because of increased inputs of nutrients such as nitrogen and phosphorus considered a worldwide issue. (Nixon, 1995; Smith et al., 1999; Percuoco et al., 2015). Ammonia can enter the aquatic environment via direct means such as municipal effluent discharges and the excretion of nitrogenous wastes from animals, and indirect means such as nitrogen fixation, air deposition, and runoff from agricultural lands (USEPA, 2013). Improper wastewater management practices in this under-served region have caused severe water quality problems, and sections of the river have experienced poor water quality with regard to dissolved oxygen, bacteria, and algae (TCEQ, 2006a).

Objective of the study

The Laguna Madre is identified as an impaired waterbody due to the presence of high concentrations of bacteria and low dissolved oxygen. The Lower Laguna Madre receives freshwaters inflows from three waterways located in the north and central part of the LRGV. The three waterways are Hidalgo Willacy Main Drain (HWMD), Raymondville Drain (RVD), and IBWC North Floodway (IBWCNF) which are not fully characterized due to insufficient data. The aim of this paper is to provide a comprehensive North and Central watersheds characterization to understand where the sources of pollution are coming from. A cyberinfrastructure database was developed to facilitate in navigating through distinct information to obtain potential sources of pollution. An ample watershed delineation was developed using as GIS platform to determine the watersheds drainage areas. The watershed characterization is essential for determining potential sources of pollution to understand the relationships associated with water quality data and flow data. Quantifying this information will help identified which of the three watersheds is contributing the most to water impairments to the Lower Laguna Madre by assessing each watershed independently. Through the cyberinfrastructure an efficient characterization will be obtained by providing a broad set of data that will include potential NPS and PS of pollution available from a variety of local and federal agencies to fully characterize the North and Central watersheds. The watershed characterization has shown to support stakeholders in the region for an optimal watershed management and enhance their decision-making process.

CHAPTER II

STUDY AREA AND METHODOLOGY

The North and Central Watershed encompasses an area of 3,116.05 km² located in south Texas in the northern and central area of the LRGV region. The LRGV is a semiarid region in south Texas bordered by Mexico to the south and the Gulf of Mexico to the east (Mahmoud et al., 2020). This watershed is comprised by three main waterways HWMD in the southwest extending to the east, Raymondville Drain RVD in the north, and IBWCNF in the southeast. The study area takes up a large plain of South Laguna Madre (LLM) Watershed Hydrologic Unit Code 12110208 (8-digit HUC). North and Central Watersheds encompasses 37% of the area in the LLM watershed. The study area has significant hydrology challenges due to flat terrain where previous studies will be considered when processing this data Previously, the study area has faced hazardous flooding events. Its elevation gradually slopes from 102 to 0 m with a high range of precipitation between 50-70 cm per year. The Arroyo Colorado is located south of the IBWCNF waterway although relatively close to one another they are not consider intersecting. In general, soils in the LRGV region consist of calcareous to neutral clays, clay loams and sandy loams (Black&Veatch, 2016). Therefore, the permeability the soils influence the drainage characteristics, clay soil is known for low permeability and causes poor drainage. It physiography zones includes the Bordas Cuesta and the Rio Grande Delta which influences the types of vegetation (Hathcock, C.R, 2014).

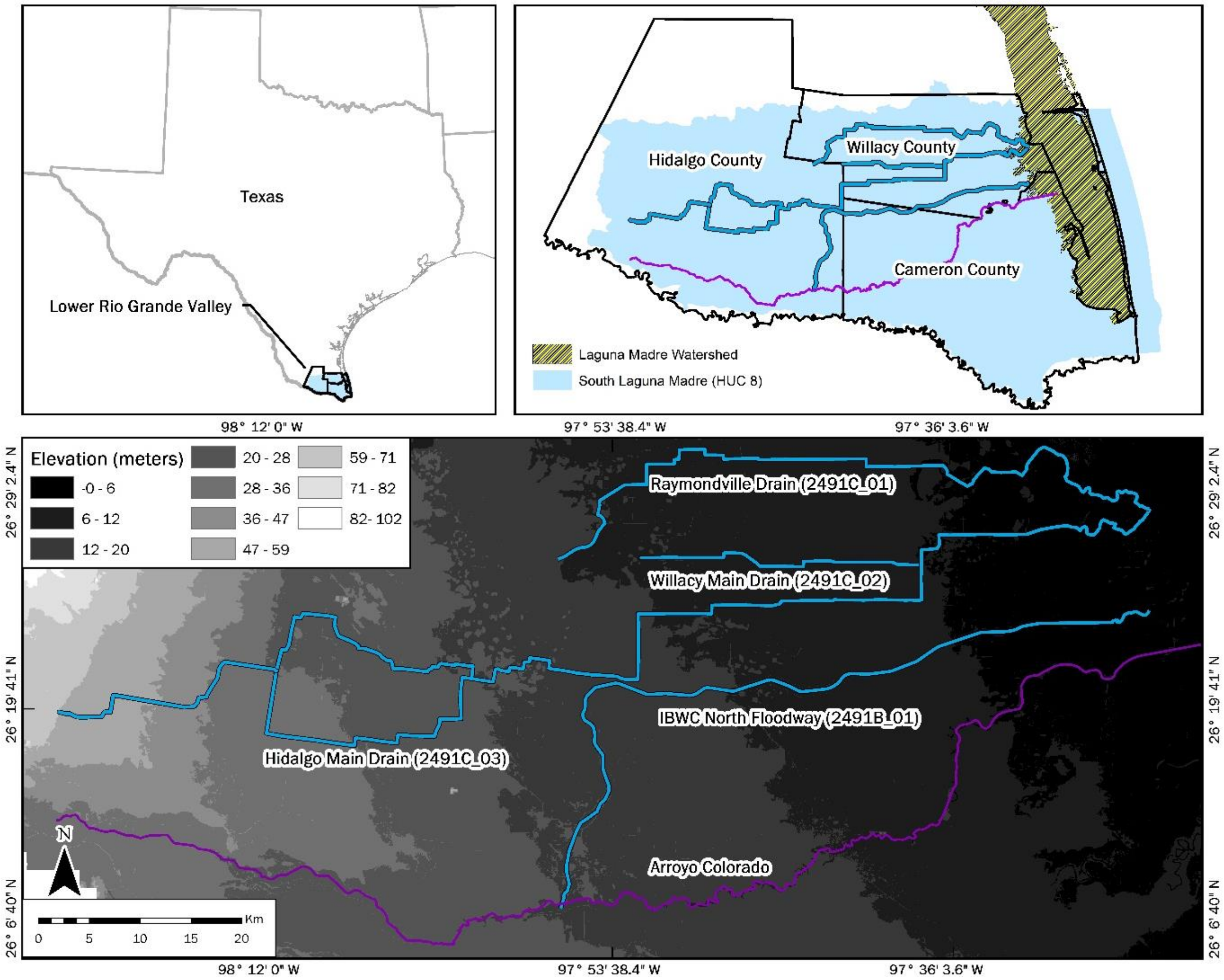


Figure 1: Location of the North and Central Watersheds

The Laguna Madre is composed of two sections: The Upper Laguna Madre and the Lower Laguna Madre (LLM) see Figure 2. The lagoon is also unusual for being one of only five hypersaline coastal ecosystems in the world (Javor, 1989; Onuf, 2002). This estuary encompasses 20% of Texas' protected coastal waters while contributing 40%–51% of the State's commercial fish catch historically as well as a common ground for migratory birds (Hernandez & Uddameri, 2013; Hedgpeth, 1947; Onuf, 2002). The LLM is the area of interest in this study since the North and Central watershed inflows to two of the three segments that are currently considered impaired.

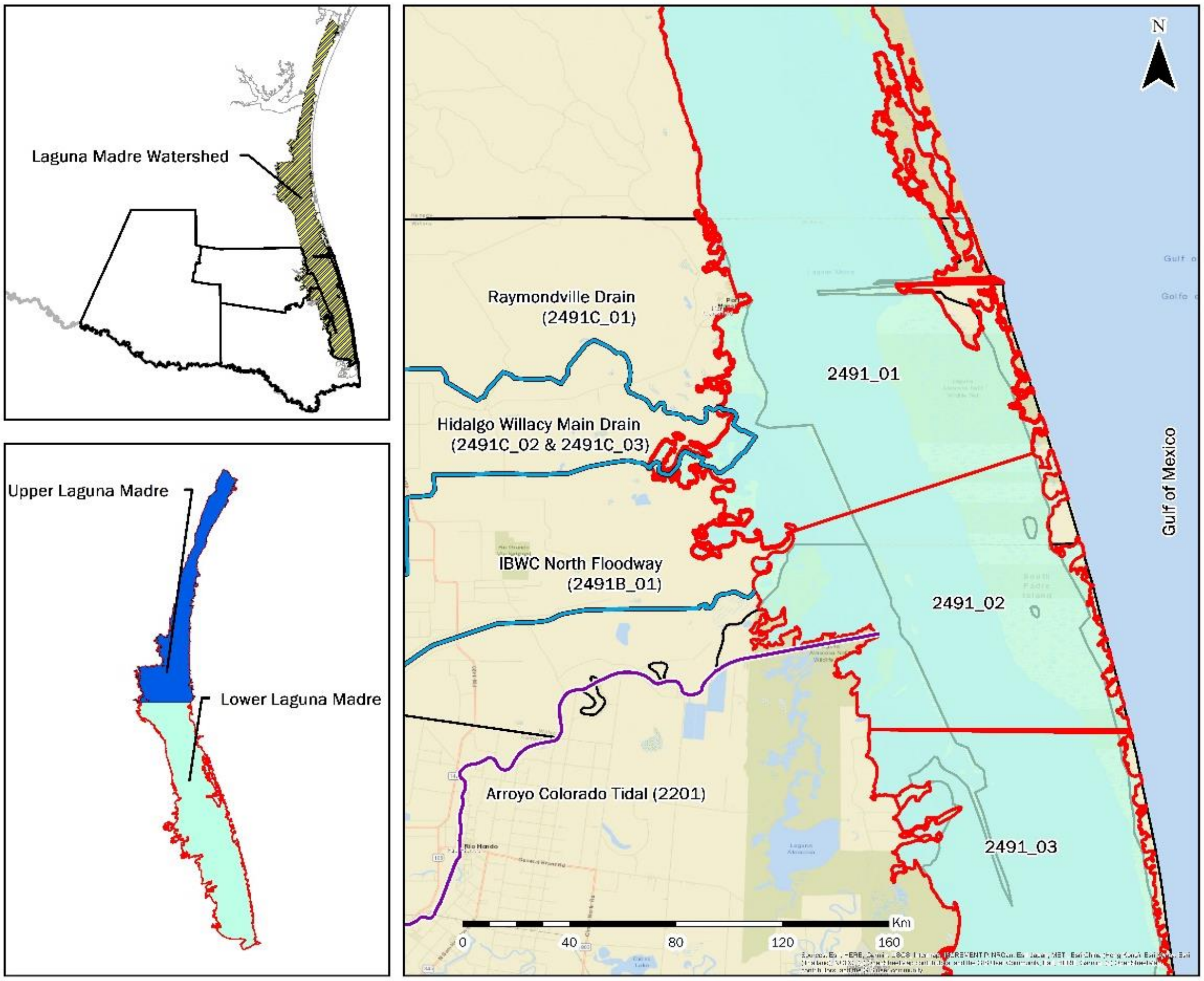


Figure 2: Lower Laguna Madre Watershed

The methodology to collect and analyze data for the characterization of the three watersheds was the acquisition of geospatial data and non-geospatial data. Geospatial data was obtained to develop a GIS database through a cyberinfrastructure to recognize the dominated attributes contributing to the watersheds. Therefore, the elaboration of watershed maps facilitated the identification of these attributes. Due to the wide inventory of data, a cyberinfrastructure was used to make data collection more efficient. Then two types of methods were used for watershed delineation to better represent the drainage areas of the watershed with respect to the terrain of the study area. In addition, NPS and PS data was obtained to fully characterized the watersheds and determine relative sources of pollution. Non-geospatial data was divided into wo sections water quality and flow data. Water quality was incorporated to determine the relationships between potential sources of pollution with the parameters found in each watershed. Available flow data was used to determine the load concentrations for each water quality parameters.

Cyberinfrastructure Development

In this study cyberinfrastructure was established by developing River and Estuary Observatory Network (REON) network. REON provides an extensive overview of all the available data from national, state and local source into this site. This platform helped in obtaining quality data for an overview of the North and Central watershed characteristics where stakeholders from the study area could support the characterization. REON.cc now serves as a cyber-collaboratory platform for engaging stakeholders with an interest in data and information for a certain location (Gutenson et al., 2020). Due to the wide inventory of data, the cyberinfrastructure also supported acquisition of geospatial data making the process more efficient. The efficient process consisted in having all the geospatial data in only one source, REON. For instance, this network is managed by a non-profit organization, Research Applied

Technology, Education, and Services (RATES), and is managed for development and deployment of high technologies to provide real-time data to enhance those who manage water resources (Kirkey et al., 2020).   The value of the REON site in this study is that it portrays special features such as metadata, properties of the layers, and layer attributes to enhance watershed characteristics.   REON site was used to incorporate geospatial data, layers, to show relative characteristics of the watersheds based on the watershed boundaries. To fully demonstrate watershed characteristics, the delineation of watershed boundaries was crucial for the assessment. Watershed delineation played an important role in this study specially for the REON site to understand the extent of the study area.

Development of Watershed Delineation

Method 1: Unenhanced Elevation Data

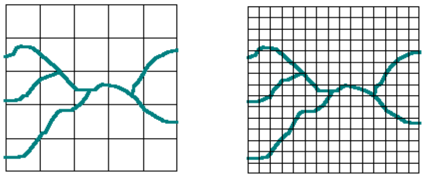
The North and Central watersheds were delineated by incorporating LIDAR elevation data extracted from a Texas state agency, Texas Natural Resources Information System (TNRIS), and using Arc-GIS Hydrology tools. The LIDAR elevation data was acquired with the collaboration of Quantum Spatial. The acquisition was conducted from January 13, 2018, through February 23, 2018. Quantum Spatial served as the prime contractor for the project and was responsible for LAS classification, all lidar products, break line production, Digital Elevation Model (DEM) production, and quality assurance (USGS, 2018). The hydrology tools encompassed the generation elevation-raster files such as, fill, flow direction and flow accumulation. D8 algorithm was used for the generation of the flow direction file. Furthermore, the flow accumulation was utilized to add pour points manually to the areas with greater cell concentration. With these files, flowlines and catchments were determined to develop North and

Central watersheds individually. Extracting characteristics of the watershed, such as stream network and catchment delineation is essential for hydrological analysis and water resource management in GIS (Zhang et al., 2013). Thus, three watershed simulations were performed to compare and contrast with a second watershed delineation process to demonstrate the accurate watershed boundaries for each North and Central watershed.

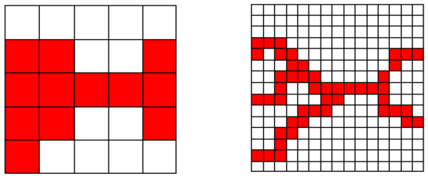
Method 2: Elevation Data Reconditioning

Since the watershed delineation is key for this study, the addition of a second method for watershed delineation was implemented to better assess the drainage areas of the watersheds. Previous studies have shown positive results for DEM reconditioning in watershed delineations in flat terrains. Also, the assessment of satellite data and National Hydrography Dataset (NHD) was considered when evaluating the waterways and other laterals for the process. The satellite data was used to determine the accurate the location of the North and Central waterways. The NHD flowlines were used to determine addition of laterals that could potentially drain into the waterways. LIDAR elevation data was reconditioned by developing several raster-elevation files to incorporate waterways into the data. This processing refers to burning waterways because the elevation data is not able to detect the waterways. Burning waterways consist of a rasterized version of the digital vector file to decrease the relative elevations of stream pixels by a uniform depth. Therefore, burning new channels into the DEM is an attempt to force alignment between topographically derived flowlines and independently-mapped hydrography (Baker et al., 2006) see figure 3. There is a significant difference between the elevation recondition data compared to the original elevation data see figures 4 and 5. Figure 4 shows a cross-section of a waterway from the North and Central waterway, RVD waterway, which results on an irregular topography. The available elevation data is limited to identify the elevation difference between the channels as a result of unpredictable cross section. However, figure 5 shows an enhanced waterway cross-section based on the topography and could potentially enhance the watershed delineation. The importance of reconditioned elevation data is that it will distinguish the change in elevation with respect to the waterway location.

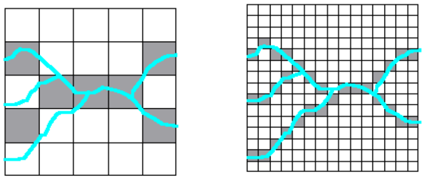
Once processing the LIDAR elevation data, the hydrology tools were used to develop elevation raster files such as fill, flow direction and flow accumulation. Only three pour points were added manually to its corresponding waterway and then automated sub watersheds were developed. With the sub watersheds delineated, the overall watershed boundaries for the three watersheds were determined based on the flow accumulation lines. The flow accumulation lines correspond to the flow path for each watershed based on elevation data. Therefore, a comparison between method 1 and method 2 will be addressed to have an optimal watershed delineation



(a) Two Conceptual Grid Layers with
Stream Network Superimposed



(b) Rasterization of the Stream Network



(c) A Gridded and "Thinned" Stream Network

Figure 3: Burning waterways to DEM (TNRCC, 1998)

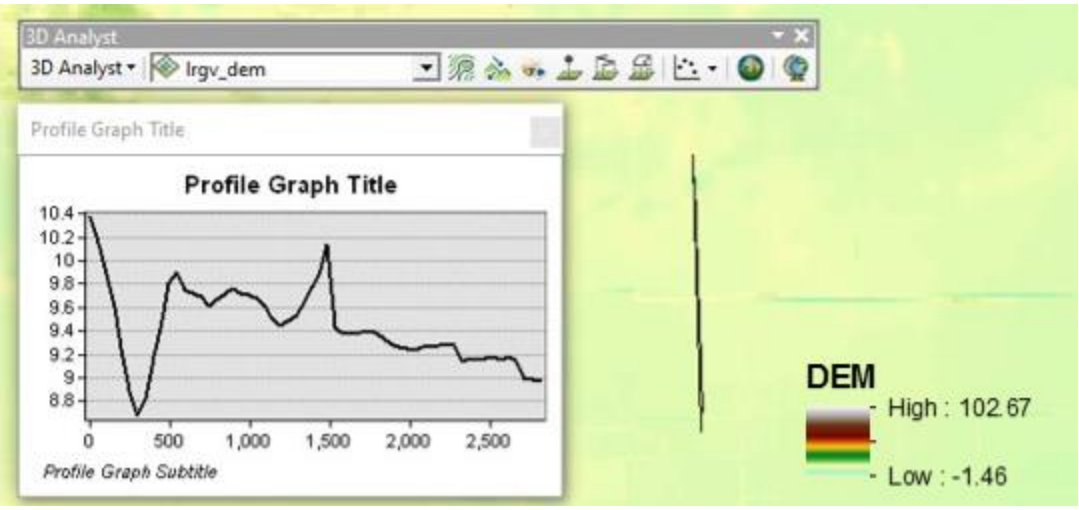


Figure 4: LIDAR Elevation data without reconditioning

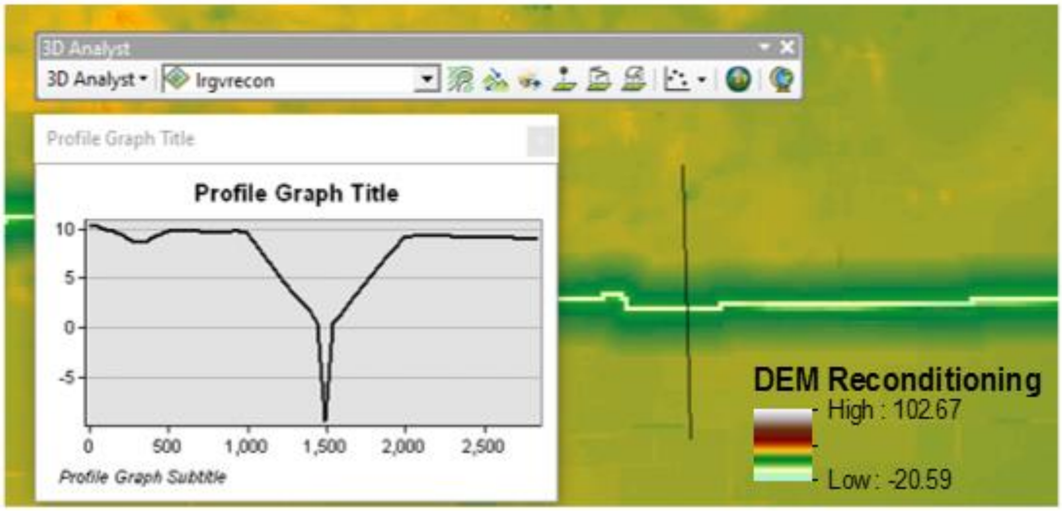


Figure 5: LIDAR elevation data reconditioned

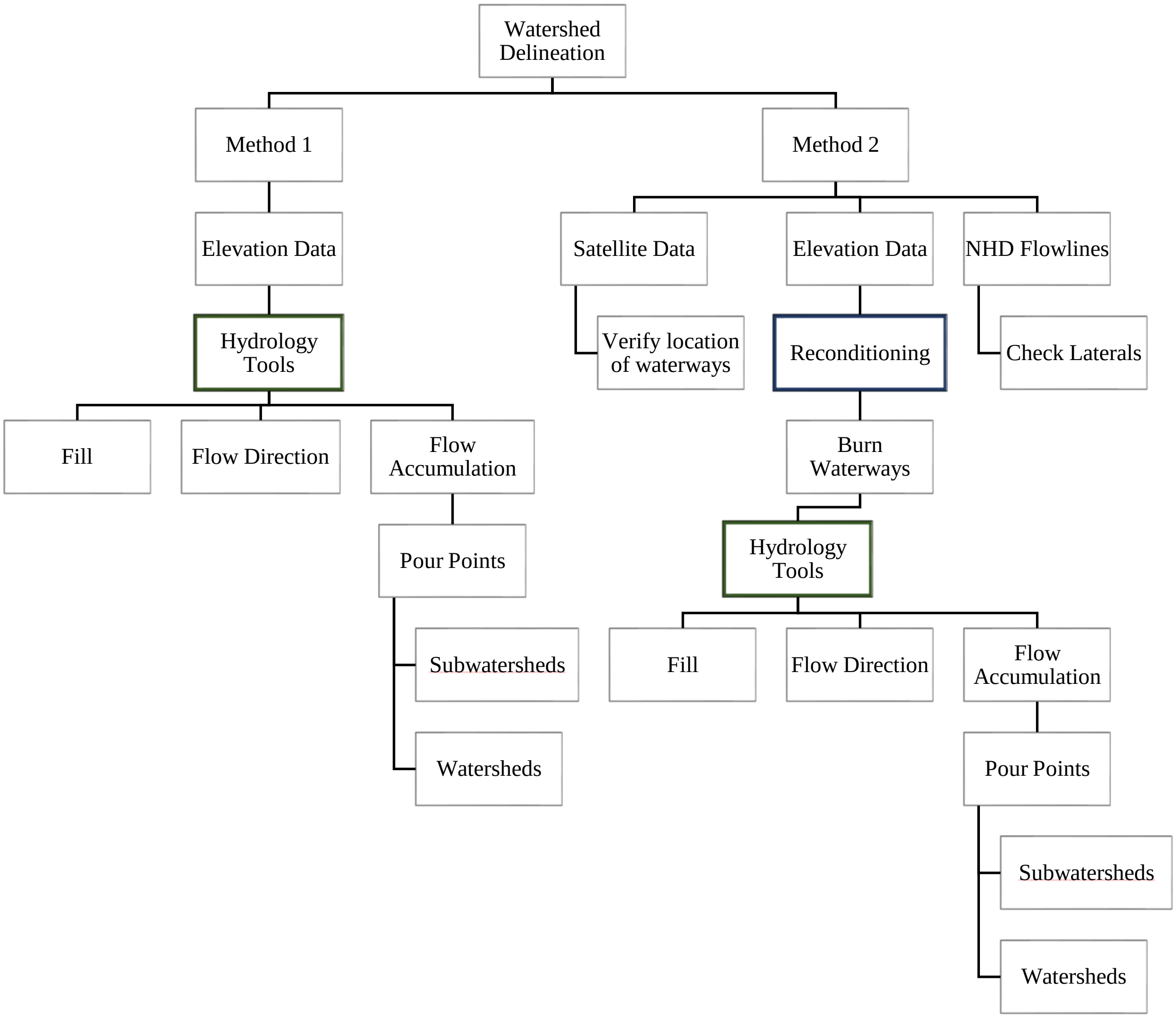


Figure 6: Watershed Delineation Methodologies

Data Collection

Geospatial Data

Generally geospatial data used in this study was to identify NPS and PS within each watershed. A summary of the data collected can be find in table 1. NPS pollutant loads through sediment and runoff courses are highly related not only to land use/cover characteristics but also to topography (L. D. Chen et al., 2003; Wu et al., 2016; Yang et al., 2012). This study integrates land cover data from 2016 National Land Cover Database (NLCD) with a spatial resolution of 30 meters to determine relative contributions of NPS in the North and Central Watersheds. The type land cover data identified as NPS encompass urban and agricultural areas only. Each watershed was treated individually to characterize the type of land cover in the area. The NPS identified within the watersheds were cultivated crops areas and urbanized areas and south Texas large ranches (STLR), species, wildlife management areas (WMA), Onsite Sewage Facility (OSSF), and colonias. STLR and colonias were extracted from TCEQ NPS group see table 1. There are currently limited studies in quantifying NPS in semi-urban areas such as LRGV, where the topography is relatively flat. Furthermore, species and wildlife management areas WMA were considered as well as part of the NPS for the effort in assessing their contaminants to the waterbodies. These were extracted from Texas Parks and Wildlife Department (TPWD). In addition, OSSF locations were mainly extracted from the colonias layer that were identified with OSSF as their wastewater collection facility. In Jeong's study, he utilized a methodology to extract OSSFs from merging address points with colonias. To estimate the number of OSSFs within the watershed, 911 address data for Cameron, Willacy and Hidalgo counties were obtained. (Jeong et al., 2019). The address points represent the number of homes within a specific area. Combing this layer with the colonias area, the acquisition of OSSFs was achieve. The colonias layer provided information about their classification and identified the type of colonias with limited wastewater disposal as well as adequate solid waste disposal. OSSFs were extracted from the red and yellow classification from colonias as well as the wastewater community section for onsite systems.

With the collaboration of local stakeholders and state-wide resources, the compilation of point sources (PS) was obtained. The PS of pollution identified in the North and Central watersheds include permitted wastewater outfalls (WWO), Texas Land Application Permit (TLAP), Municipal Solid Waste (MSW), and Municipal Separate Storm Sewer System (MS4). The WWO and the TLAP locations were obtained from a state agency, TCEQ. There were two types of WWOs identified in these watersheds: domestic and industrial wastewater discharge. Domestic WWOs discharge less than 1 million gallon per day (MGD) while the ones with a discharge greater than 1 MGD may be either domestic sources or industrial wastewater treatment plant effluent (TCEQ, 2010). MSW locations were acquired from TCEQ NPS group. Desalination plants were obtained from Texas Water Development Board to support the PS contribution to the watersheds.

Table 1: Geospatial Data Source

Data	Source	Year	Usage
LIDAR Data	USGS, TNRIS	2018	Watershed Delineation
Hydrograph (NHD)	USGS	2012-2019	Watershed Delineation
Land Cover	National Land Cover Database	2016	NPS: Urbanized Areas and Cultivated Crops
Large Ranches South Texas	TCEQ NPS Team	2018	NPS
Texas Land Application Permit	TCEQ NPS Team	N/A	PS
Wastewater Outfalls	TCEQ Website	N/A	PS
Municipal Solid Waste	TCEQ NPS Team	N/A	PS
On-site Sewage Facility	Extracted from Colonias and Address Points	2021	PS
MS4s	TCEQ NPS Team	N/A	PS
Colonias	TCEQ NPS Team	2015	PS; extract OSSF points
Desalination Plants	Texas Water Development Board (TWDB)	2021	PS
IBWC Gage Stations	IBWC		PS
SWQMs Stations	TCEQ Website		PS
Address Points	TNRIS	2018	To extract OSSFs points

Non-Geospatial Data

Water Quality. There was water quality data obtained for the three watersheds. For the HWMD and RVD watersheds, water quality data was obtained by the Clean Rivers Program(CRP) with only 8 samples available from 2017 to 2019. The data was obtained in a quarterly basis with a total period of 2 years. For the IBWCNF watershed water quality data was extracted from SWQMs with 29 samples from 2012 to 2019. The data was obtained in a quarterly basis with a total period of 7 years. The water quality parameters assessed in this study includes: Bacteria, Ammonia, Total Nitrogen (TKN), Total Phosphorus (TP), Nitrate & Nitrate, and Chlorophyll-a. A statistical software was used, R studio, to developed boxplots for each parameter. Water quality parameters were assessed with comparison with the three watersheds.

Flow Data. There is currently limited flow data for HWMD and RVD waterways. The flow data available was obtained from Nueces River Authority CRP HWMD station 22003 and RVD 22004. The data was quantified at a quarter basis for the period of two year where only 8 readings were available for each site. These stations are located east of US-77 and were added to the CRP Monitoring Schedule back in 2018 (CRP, 2019). IBWCNF has two stations available for flow data readings monitored by USIBWC. 08470100 North Floodway West of Mercedes (Mercedes) and 08470200 North Floodway Near Sebastian (Sebastian) are the stations with 135,542 and 304,982 observations from 2012 to 2020.

The Mercedes station is located within the IBWCNF waterway with coordinates of 26° 8′ 58″, -97° 55′ 39″ (WGS 84) and has an elevation of 0.05 m. The Mercedes datasets presented values between 2015 to 2020 with a sample size of 140,261 observations. 2016 flow values were removed from the sample data since values were zeros. The sample data consisted of intervals of 15 minutes with respect to flow in cubic meter per second (CMS). Boxplots were created using R studio for annual and monthly flow values. The outliers from the boxplots were neglected to have a better representation of the sample distribution. The big storm events were not shown in the boxplots since the outliers were neglected.

The coordinates of the Sebastian station are 26° 18′ 53″, -97° 46′ 38″ (WGS 84). This station is mainly used as a flood warning station with an elevation of 0.11 m. The Sebastian datasets presented values between 2012 to 2020 with a sample size of 304,982 observations. The sample data consisted of intervals of 15 minutes with respect to flow in cubic meter per second

(CMS). The outliers from the boxplots where neglected to have a better representation of the sample distribution as well as the Mercedes dataset. Therefore, the big storm events flow readings were not shown in the boxplots. The Sebastian station was used as the flow data for the calculation of flow concentrations because the water quality samples were collected near this station.

Table 2: Non-Geospatial Data Sources Collection

Data	Segment	Source	Year	Usage
Water Quality	HWMD, RVD	Clean River Program (CRP)	2017-2019	Characterization
Water Quality	IBWCNF	Surface Water Quality Monitoring (SWQM)	2011-2019	Characterization
Flow Data	IBWCNF	U.S. Section of the International Boundary and Water Commission (USIBWC)	2012-2020	Load Concentrations

CHAPTER III

RESULTS

REON Cyberinfrastructure

With the collaboration of REON, cyberinfrastructure site, both data collection and the development of maps were accomplished. Three maps were created: Watershed delineation showing method 2 results, NPS, and PS maps. The maps created facilitated the watershed characterization by integrating geospatial data for NPS and PS for each watershed individually. The development of maps portrayed in the cyberinfrastructure helped stakeholders collaborate in the characterization by providing inputs for each potential source that could contaminate in the area. The web user interface at the regional level is available for every stakeholder no matter time or location.

The first step for the watershed characterization was to develop the watershed delineation for the three watersheds then the results were uploaded to REON website to show watershed boundaries. Additionally, NPS and PS layers were included to each watershed to facilitate the characterization process. Based on EPA watershed characterization.

Watershed Delineation

This section introduces for the watershed delineation results for the study area. Although the watershed delineation process is not the main objective of this study, it is fundamental for the overall characterization. The watershed delineation contributes to this study by using two distinct methods to establish which watershed boundaries will have optimal results and contribute to the characterization.

Both methods generated a broad set of elevation raster-files for the HWMD, RVD, and IBWCNF watersheds areas. For method 1 the elevation raster-files presented a deficiency in the resolution because the region is relatively flat. Generally, the watershed slopes from west to east through the heart of the LRGV with an average slope of fewer than 0.3 meters per kilometer (Flores et al., 2017). Overall, its flat terrain varies from 0 m to 100 m. One difficulty that challenges all automated delineation methods is the establishment of channel networks in flat regions of DEMs (Zhang et al., 2013). The flat topography in the study area affected the watershed delineation in some areas. The challenge with this method was that some watersheds were overlapping with other waterways. To address this discrepancy the addition of pour points to the areas where the overlapping occurred between the waterways and their neighboring watersheds facilitated the improvement for the watershed delineation. Also, the resolution of the elevation raster-files was changed from 1 m to 50 m which contributed to the reduction of file size and thus provided an efficient analysis. Yet in certain topographic settings, the un-enhanced automated methods were inadequate and gave frequent large error. Unenhanced Coastal Plain delineations in particular had many errors due to the low-relief of drainage divides and the extent of ditching (Baker et al., 2006). Therefore, neglecting the type of terrain in the area could potentially affect the results for the watershed delineation.

Method 1 results show to have the flow accumulation lines synchronizing only with IBWNF waterway, but the other flow accumulation lines were limited to represent the actual path of the waterways see figure 7. For instance, some pour points were added in areas where there were no flow accumulation lines. Method 1 has an acceptable outcome but is limited to provide optimal results for the watershed boundaries.

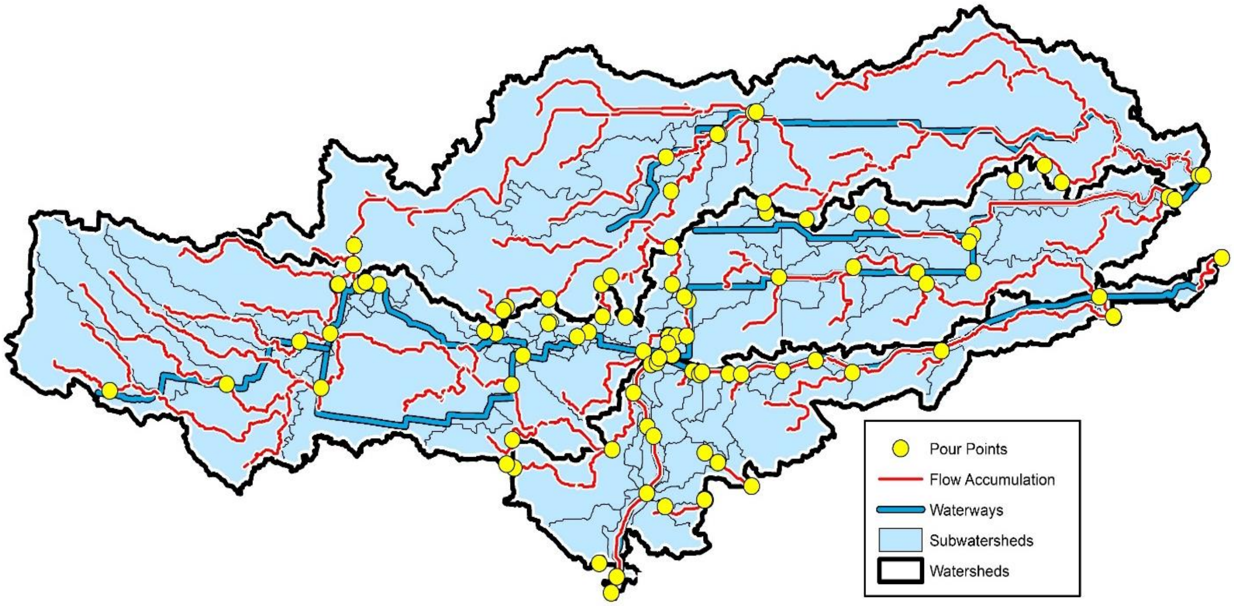


Figure 7: Method 1 results for the watersheds

Method 2 encompass a comprehensive LIDAR elevation data reconditioning to well display the North and Central watersheds characteristics. The burning waterways to the elevation data contribute to the overall delineation. In this method the flow accumulation lines embody the actual waterways in mostly all the watersheds. The watershed boundaries correspond to the flowlines and follows an enhanced methodology for the type terrain in the region. Therefore, this method was used for the watershed boundaries in this study to fully be characterized the North and Central watersheds.

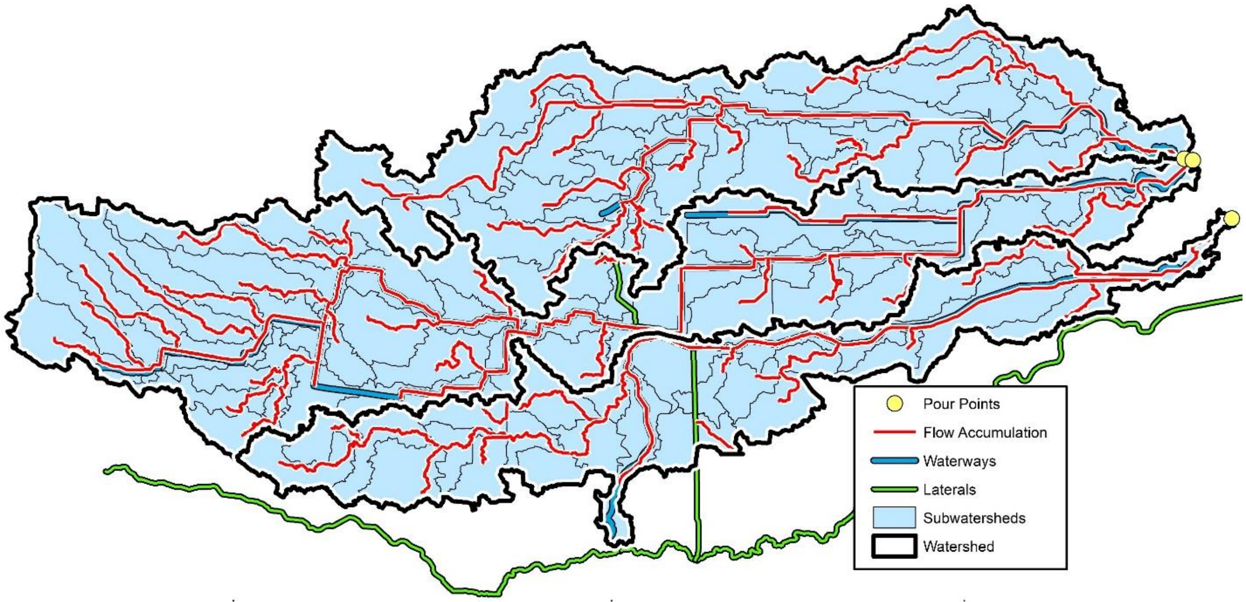


Figure 8: Method 2 results for the watersheds

Watershed Results

The North and Central watersheds presented a total area of 3,116.05 km² from which HWMD watershed presented an area of 1,357 km² , RVD watershed 1,021 km², and IBWCNF watershed has 737 km².

HWMD watershed covers 68% of its area in Hidalgo County, 13% in Willacy County, and a small portion of 1% in Cameron County. Since this watershed has the largest area among the North and Central watersheds, it has the potential to contribute to most of the water impairments to Lower Laguna Madre. This watershed covers a wide central area of the LRGV region. It extends across the cities of Alton, Palmhurst, Mission, McAllen, Edinburg, Elsa, Edcouch, La Villa and Lyford. Also, it covers the McAllen-Edinburg-Mission Metropolitan Statistical Area (MSA) of the LRGV region which is ranked 5th largest in the state of Texas.

The RVD watershed, located in the North area of the LRGV region, covers 30.7 % in Hidalgo County, 68.9% in Willacy County, and 0.4% in Kennedy County. The city of

Raymondville, San Perlita and a northeast portion of the city of Edinburg are the only cities within the watershed.

IBWCNF watershed is the smallest watershed, covering 52.7 % in Hidalgo County, 23.6% in Willacy County, and 23.6% in Cameron County. This watershed is within the southern area of the North and Central watersheds and intersects with the Arroyo Colorado watershed. The cities of McAllen, Pharr, San Juan, Alamo, Dona, Weslaco, Mercedes, and Santa Rosa are included in the IBWCNF watershed. The IBWCNF branches off of the Main Floodway at the Llano Grande, a shallow lake located southwest of the city of Mercedes(Arroyo Colorado Watershed Partnership & Texas Sea Grant Pursuant, 2007). IBWCNF waterway is considered a man-made waterway approximately 77 km long and is used to divert Arroyo Colorado’s flow. The city of Mercedes is upstream of IBWCNF flow and downstream of the Arroyo Colorado waterway when the flow is exceeding its capacity. During flood conditions, which the IBWC defines as flow exceeding 39.64 cubic meter per second, approximately 80 percent of the flow in the Arroyo Colorado is diverted to the IBWCNF (IBWC, 2003).

Table 3: Watershed Results

	HWMD	RVD	IBWNF
Watershed Area (km²)	1,357	1,021	737
Number of Subwatersheds	91	72	73
Hidalgo County	68 %	30.7 %	52.7 %
Willacy County	13 %	68.9%	23.6%
Cameron County	1 %	0%	23.6%

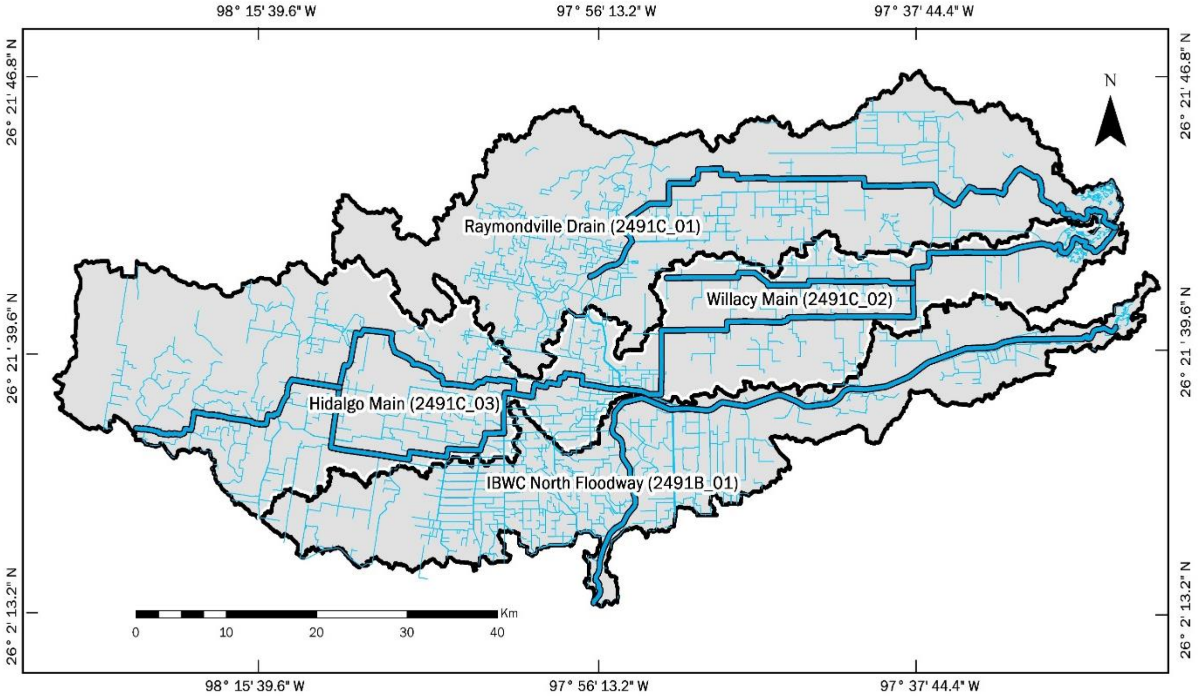


Figure 9: North and Central watersheds

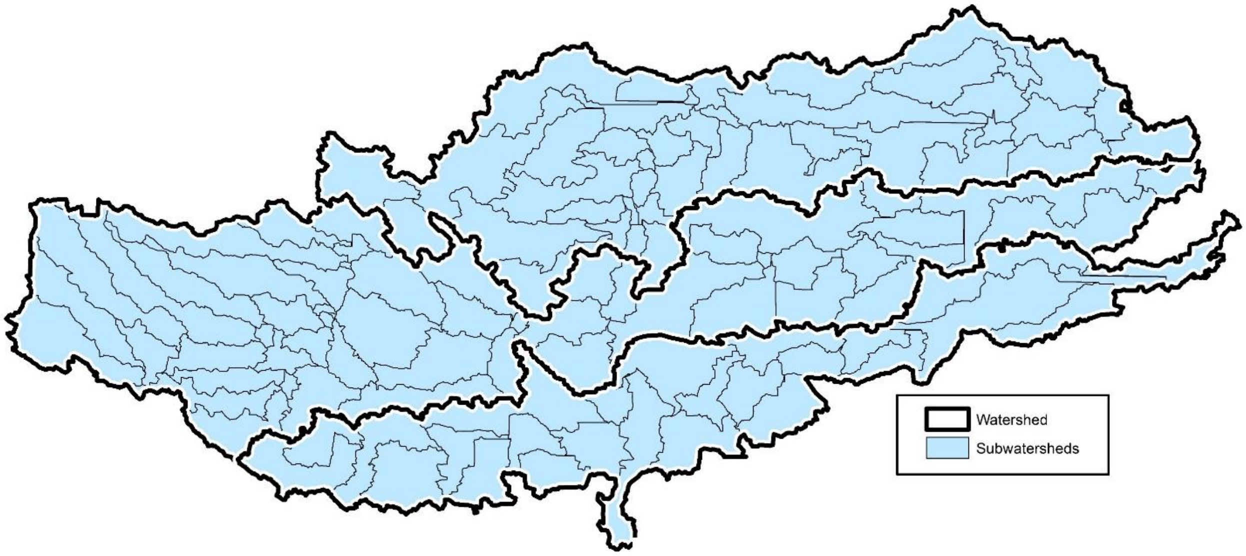


Figure 10: North and Central Subwatersheds

Non-Point Sources

In this section, the watershed that potentially contributes the most with NPS will be identified. The relevative contributions of NPS were determined to identify the greater source of pollution among these watersheds see Fgure 9. The predominant land cover for the North and Central watersheds is cultivated crops representing 53% of the total area located mostly in the northeast sector of the watersheds. Generally, this type of land use is within the downstream tributary areas of the watersheds which ultimately carries significant NPS. Urban areas are another land cover type that has shown to be contributing to NPS. Urbanization areas within the North and Central Watersheds cover 13% of the total area. In peri-urban areas, agricultural/rural NPS and urban NPS are two types of sources that have gained considerable concern because urban expansion and agriculture intensification may act as a source or sink for contaminants to move toward surface water bodies (Gooddy et al., 2014). Agricultural and urban areas in a watershed have shown in previous studies to be the main contributors to NPS.

STLR were found near the coast of the three watersheds. The main concern with this type of NPS is the exposure to several hazardous contaminants from the practice of livestock. The improper management of livestock wastes (manure) can cause surface and groundwater pollution. Water pollution from animal production systems can be by direct discharge, runoff, and/or seepage of pollutants to surface or ground water (Schumacher, 2002). Moreover, OSSFs are designed to treat domestic wastewater using a septic tank for screening and pretreatment and a drain field where pretreated septic effluent is distributed for soil infiltration and final treatment by naturally existing microorganisms (J. Jeong et al., 2011).

Species and WMA were found close to the coast of each watershed. These NPS contribute to high bacteria loadings to waterbodies from wildlife in the region. Grazing animals and wildlife can also negatively affect the quality of runoff and waterbodies with bacterial contamination (Jeong et al., 2019). In Texas, non-avian wildlife, such as deer or feral hogs, are commonly found to be significant contributors of bacteria to natural streams (Jeong et al., 2019;

Wagner & Moench, 2009). In addition, colonias are consider the most distressed areas in the United States. The term means settlement or neighborhood and is commonly used to refer to unincorporated rural and peri-urban subdivisions along Texas' border with Mexico (Olmstead, 2004). They are usually found along the U.S.- Mexico border which often lack necessities such as sewer systems, drinkable water and overall a sanitary housing. Consequently, colonias can be a potential contributor of NPS since they lack adequate solid waste disposal, and wastewater systems. TCEQ created a classification system to identify the colonias with adequate utilities and the ones that lack basic utilities see Table 5. The red and yellow classification were the ones selected for colonias that potentially carry NPS see Figure 11. Based on the priority classification by the Rural Community Assistance Partnership, OSSFs located in the colonias having a health hazard (red colonias) were assumed to have a greater failure rate (70%). Conversely, a 30% failure rate (determined based on local expert knowledge) was assigned to areas having the lower priority ratings (non-red colonias)(Jeong et al., 2019).

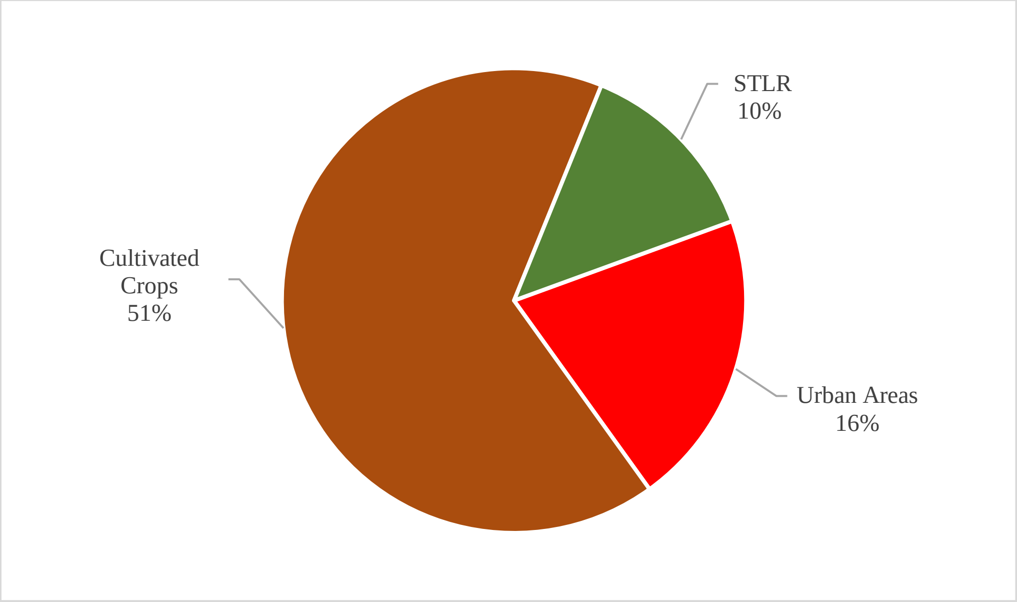


Figure 11: Non-point Contributions

The HWMD watershed covers about 73.1% of NPS from the total area of the watershed. Approximately the HWMD watershed cultivated crops corresponds to 46.6%, and 20.1% of urbanized areas. Urban growth in the watershed will primarily occur in areas that are currently cultivated and will influence the region's water quality (Flores et al., 2017). Therefore, the HWMD watershed was identified with the highest urban areas among the other watersheds with respect to their watershed area. The watershed encompasses 6.4% of STLR areas. Only El Suaz ranch pertains to the watershed. These STLR areas have grazing livestock activities which ultimately carries significant levels of bacteria. There were 46 species identified in this watershed along with two WMA units. La palomas units Longoria and Fredrick were found where they possess hunting activities for their diversity of species. 4,591 OSSFs were found in the HWMD watershed from a total of 9,170 in the North and Central watersheds. All OSSFs have potential adverse environmental impact if they are improperly functioning, but those closer to streams present an elevated risk (Flores et al., 2017). Although there were more OSSFs identified in this watershed, it is less with respect to the overall watershed area with a ratio of 3.38 The watershed has 336 colonias where 80 are classified with limited solid waste disposal while 33 lack adequate solid waste and wastewater disposal. The total area of the colonias in the watershed is 26.8km^2. Many homes cannot meet county building codes because they lack indoor bathrooms and plumbing, a prerequisite for connection to local water lines and sewage systems (TCEQ, 2007).

The RVD watershed covers almost 86% of NPS from the total area of the watershed. The watershed has 51% of cultivated crops and only 2% of urban areas. The RVD watershed encompasses 19% of STLR areas. King Ranch, East Foundation, and El Suaz are the ranches that cover the watershed. Not only the agriculture activities take place within the STLR areas, but grazing livestock as well which causes relative contribution of bacteria. Fecal pollution brought to the rivers through surface runoff and soil leaching represents the non-point source; its origin can be the wild animals and grazing livestock feces and cattle manure spread on cultivated areas (Atwill et al., 2002;Collins & Rutherford, 2004;Tyrrel & Quinton, 2003). There were 56 OSSFs were identified in the watershed. The RVD watershed has only 13 colonias recorded from which 1 is limited to solid waste disposal and 3 lack of basic utilities. Colonias within the watershed cover an area of 21.6 km^2.

The IBWCNF watershed covers about 100% of NPS from the total area of the watershed. IBWCNF watershed corresponds to 73% of cultivated crops and 13% of urban areas. This watershed has the highest contribution of agricultural lands. Agricultural lands have been identified with ammonia and nitrogen According to EPA, the watersheds could be affected by the level of decomposition of organic matters and some fertilizers used in agriculture. This watershed covers a portion of el Suaz ranch with 5% of STLR areas. There were 4,523 OSSFs identified in this watershed corresponding to a 6.33 ratio between the total OSSFs to the total area of the watersheds. The colonias cover an area of 23.4 km^2 within IBWCNF watershed. This watershed has 216 colonias from which 65 only lack of proper solid waste disposal and 51 lacks both solid waste and wastewater disposal.

Therefore, the HWMD watershed was identified with the highest urban areas among the other watersheds with respect to their watershed area. The RVD and IBWCNF watersheds were the ones to have greater NPS covered by cultivated crops. (Jeong et al., 2019) found that croplands contributed the most to nitrogen and phosphorus. The RVD watershed was the highest with STLR areas.

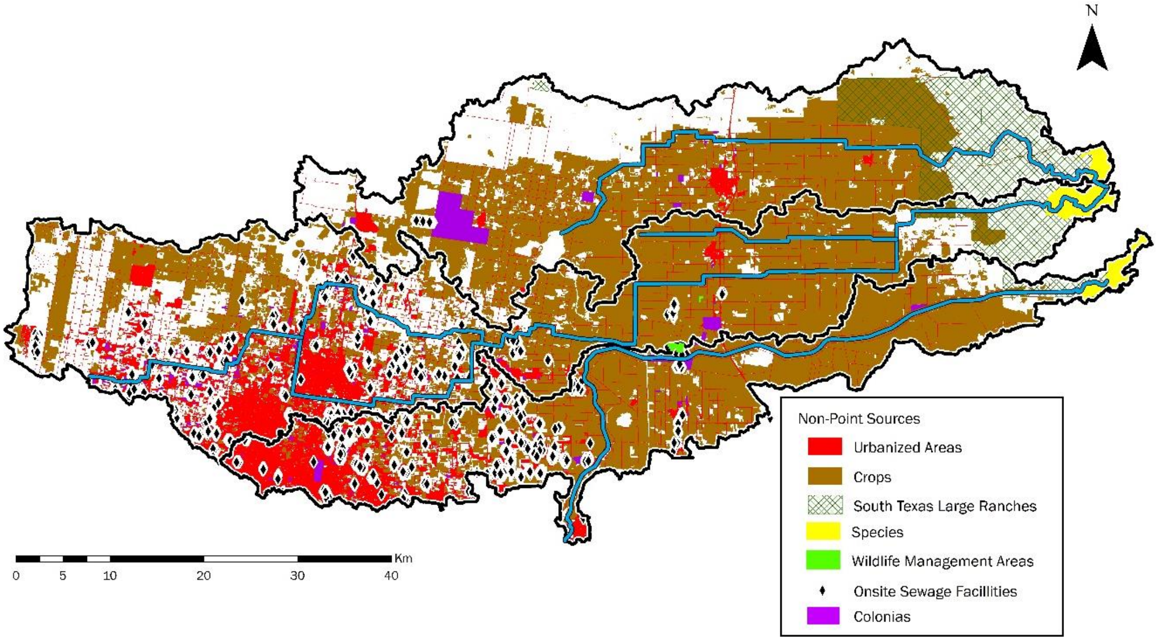


Figure 12:North and Central Watersheds Non-Point Sources

Table 4: NPS with respect to North and Central Watersheds Areas

	HWMD	RVD	IBWNF
Urbanized Areas	20.1%	4.5%	24.3%
Cultivated Crops	46.6%	52.3%	58.5%
STLR	6.4%	20.3%	3.8%
Species*	42	106	151
Wildlife Management Areas*	2	0	2
Onsite Sewage Facilities	4,591	56	4,523
Colonias	336	13	216

Source: Land Cover Data, 2016. TCEQ

*Quantified data

Table 5:NPS Quantities Normalized

	HWMD	RVD	IBWNF
Species	0.03	0.10	0.20
Wildlife Management Areas (WMA)	0.00	0.00	0.00
Onsite Sewage Facilities (OSSFs)	3.38	0.05	6.13
Colonias	0.25	0.01	0.29

Table 6: NPS with respect to North and Central Watersheds Total Area

	HWMD	RVD	IBWNF
Urbanized Areas	8.8%	1.5%	5.8%
Cultivated Crops	20.3%	17.1%	23.7%
STLR	3.0%	6.5%	0.7%
Totals	32.1%	25.0%	30.2%

Source: Land Cover Data, 2016. TCEQ

Table 7: Colonia Classification System

	Green	Yellow	Red	Grey
Drinkable Water	Yes	Yes	No	-
Wastewater Disposal	Yes	Yes	No	-
Approved Subdivision Plats	Yes	Yes	No	-
Paved Roads	Yes	No	No	-
Adequate Drainage	Yes	No	No	-
Solid Waste	Yes	No	No	-

Source: TCEQ, August 2013

Point Source

There is a substantial contribution of bacteria from wastewater treatment plants (WWTP) which potential discharges to the waterways.   Point source fecal contamination of water normally results from direct entry of wastewater from a municipal treatment plant into a water body (Jeong et al., 2019) . According to TCEQ, TLPA refers to the spreading of sewage from several applications such as surface irrigation, evaporation, drainfields or subsurface land application. MS4s are identified to discharge significant levels of contaminants to the United States waterbodies. MS4 discharges are now one of the major sources of water pollution in the nation (Abrams, 2012). These sources are potential contributors to water quality impairments to the North and Central waterways.

The HWMD watershed showed 11 WWOs from which 5 were found to discharge less than 1 MGD and the rest discharged more the 1 MGD. There were 8 TLAPs found in the upstream of the watershed. Currently, there are 2 active MSW facilities in the HWMD watershed. This watershed has a total of 17 MSW facilities recorded from which 4 are considered closed facilities, 4 are inactive, 2 post closed and the rest are not constructed. Potentially, these facilities can not only affect the surface water within the watershed but groundwater as well. The closed landfills, many of which are unlined and poorly capped, may be sources of a large number of organic compounds known as emerging contaminants (ECs) to surrounding groundwater and surface water (Andrews et al., 2012). HWMD watershed covers 13% of MS4s. There are currently 7 MS4s permitted areas within the HWMD watershed. Theses MS4s include the cities of Alton, Pharr, Palmhurst, Mission, McAllen, Edinburg, and Edcouch. HWMD watershed has the highest MS4s areas among the other watersheds. Polluted stormwater runoff is commonly transported through municipal separate storm sewer systems (MS4s), and then often discharged, untreated, into local water bodies (EPA, n.d.-a) Therefore, the HWMD watershed shows severe impact by the PS compared to the other watersheds

Although the RVD watershed has a greater area compared to the IBWCNF watershed, it is limited with PS. 5 WWOs were identified within the watershed boundaries from which 3 are considered industrial wastewater effluent and 2 domestics. Only 4 TLAPs were found in the RVD watershed. Currently, the City of Edinburg Landfill is an active MSW in the RVD watershed. A total of 4 MSWs were identified in the RVD watershed: 2 not constructed, 1 closed and 1 post closed MSWs. RVD watershed is considered to contribute to 0% of MS4s with only 0.3% of the city of Edinburg's MS4 was found. This watershed covers almost the entire Willacy County which is identified limited in MS4s.

The IBWCNF watershed presents 9 WWOs from which 4 are domestic and 5 industrial wastewater effluent. For instance, only 3 TLAP was found, and 3 active MSWs were identified. These PS are mainly located within the upstream of the watershed. As a result, it is important to identify the potential PS of the downstream area of the Arroyo Colorado watershed that diverts to the IBWCNF watershed. The IBWCNF watershed has 7% of MS4s permitted areas. The watershed MS4s permitted area includes the cities of McAllen, Edinburg, Pharr, San Juan, Alamo, Donna, Primera, Mercedes, Santa Rosa, Town of Combes, and Weslaco. Consequently, it is important to improve stormwater management within these areas to mitigate PS. Unlike sanitary sewer systems, MS4 systems do not treat the storm water collected; instead MS4s are required to develop and implement storm water management programs (SWMP) that reduce the amount of contaminants that enter the system and prohibit illicit discharges. (Abrams 2012).

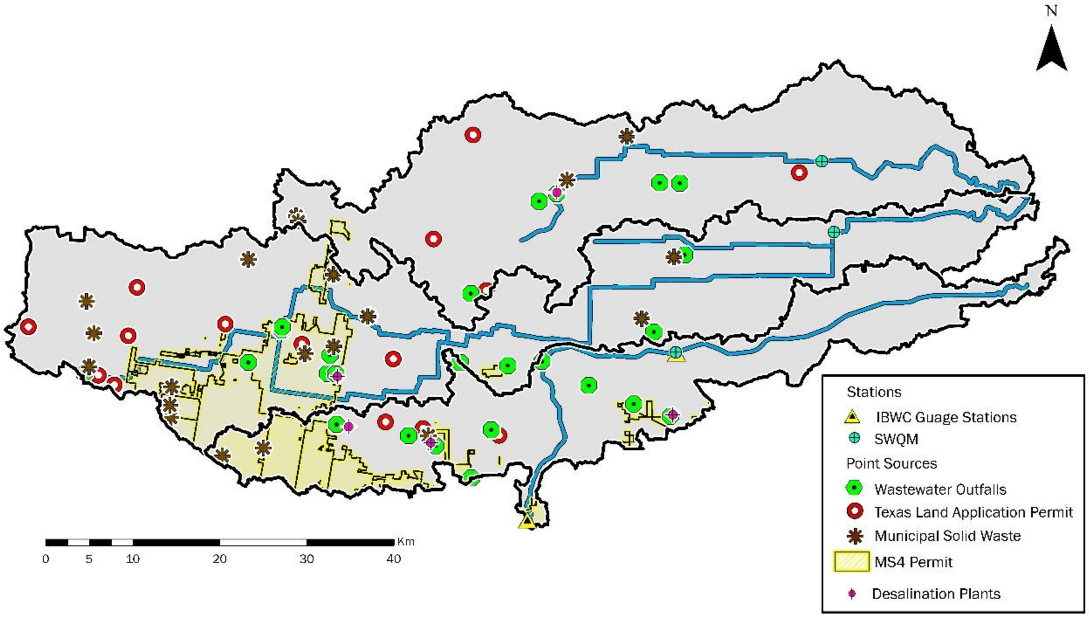


Figure 13: North and Central Watersheds Point Sources

Table 8: PS for North and Central Watersheds

	HWMD	RVD	IBWNF	Total
Stations				
IBWC Gauge Stations	0	0	2	2
SWQM	1	1	1	3
Point Sources				
Texas Land Application Permit	8	4	3	15
Wastewater Outfalls	11	5	9	25
Municipal Solid Waste	17	4	3	24
MS4 Permit	8	1	12	21
Desalination Plants	1	1	2	4

Source: TCEQ

Table 9: PS Normalized Quantities

	HWMD	RVD	IBWNF	Total
Point Sources				
Texas Land Application Permit	0.006	0.004	0.004	0.014
Wastewater Outfalls	0.008	0.005	0.012	0.025
Municipal Solid Waste	0.013	0.004	0.004	0.021
OSSF	3.383	0.055	6.133	9.571
MS4 Permit	0.006	0.001	0.016	0.023
Colonias	0.248	0.013	0.293	0.553
Desalination Plants	0.001	0.001	0.003	0.004
Total	3.66	0.082	6.47	10.211

Water Quality Parameters

HWMD watershed has E. Coli levels higher than the action level from 2017 and 2019. In 2019, the E. Coli levels were above 2000 MPN/100ML. The existence of high levels of bacteria are caused by a variety of NPS and PS sources such as: urban runoff, agricultural lands, ranches, WWO, OSSF, MS4s, and colonias. Ammonia levels in this watershed were below the action level with 2.7 MGL AS N which is consider the highest record. In 2018, the TKN levels were the highest compared to the other years with more than 3.0 MGL AS N. The presence of TKN in HWMD watershed, according to EPA, are sources of failing septic systems, croplands, and industrial discharges. TP levels barely exceed the action level of 0.7 MGL with maximum value of 0.8 MG/L in 2017. Moreover, the Nitrite and Nitrate levels found in the watershed are higher than the action level. Chlorophyll-a levels identified surpassed the action level of 14 UGL for the three years. In 2018, chlorophyll-a had the highest level of 98 UGL.

RVD watershed show to have the higher levels of E. COLI for the past 5 years compared to the other watersheds which suggests that there many septic tanks that can be leaking, sewage overflows, poorly structured sewage systems and polluted stormwater runoff. However, ammonia levels for RVD watershed are acceptable since they are below the action level of 0.33 MG/L with a maximum value of 0.2 MG/L in 2018 and 2019. The TKN levels mainly surpasses the action level of 1.0 MG/L in 2018 and 2019. TP levels were lower in all the years recorded with a maximum value of 0.4 MG/L in 2019. According to USGS, soil erosion is the main source of total phosphorus during flooding events that can be the potential sources in these watersheds. Nitrite and Nitrate levels surpass only in 2017, but the highest level identified was almost 6 MGL AS N in 2019. For Chlorophyll-a levels, the RVD watershed, showed it highest level of 70 uGL in 2019.

In the IBWCNF watershed the levels of bacteria were identified to be higher in 2013, 2014, 2015, and 2019. The highest level was around 8000 MPN/100ML in 2013. The bacteria levels from 2016 through 2018 were determined to be slightly below the action level of 126 MPN/100ML. The results suggest, according to (Jeong et al., 2019), that the watershed is affected by wildlife with small contributions of domestic animals and point sources. The ammonia levels were identified to be less than the action level during all the years. This indicates that the watershed is limited to carry significant levels of ammonia from agricultural runoff. TKN levels show to be relatively higher than the action level with the highest of 2 MGL AS N in 2018. High levels of total nitrogen are caused by decomposition of detritus and any anthropogenic loadings (Uddameri et al., 2018). TP levels were lower than the action level of 0.7. The IBWNF watershed is limited to algae growth since TP levels are low. Nitrite and Nitrate levels are higher than the action levels, 7 MGL was the highest level recorded in 2015. Chlorophyll-a levels were determined to be higher than the action levels for nearly all the years. This implies the presence of excess quantities of algae.

Table 10: North and Central Water Quality Summaries

		Bacteria MPN/100mL	Ammonia mg/L AS N	TKN mg/L AS N	TKN-Ammonia mg/L AS N	TP mg/L AS P	Nitrite +Nitrate mg/L AS N	Chlorophyll-a ug/L
HWMD 8 samples	Mean	559	0.1	2.0	1.8	0.6	3.5	43.8
	Max	2200	0.3	3.6	3.6	0.8	5.7	98.5
	Min	10	0.0	1.0	0.9	0.2	0.0	13.5
	Median	100	0.2	1.8	1.6	0.7	3.9	25.5
	SD	819.	0.10	0.9	0.9	0.3	2.1	34.3
RVD 8 Samples	Mean	846	0.1	1.7	1.5	0.2	1.9	28.7
	Max	2400	0.2	3.1	3	0.4	5.7	67.0
	Min	74	0.0	0.4	0.3	0.1	0.6	3.8
	Median	185	0.1	1.5	1.3	0.2	1.5	26.6
	SD	986.4	0.1	0.9	0.9	0.1	1.6	19.9
IBWNF 25 Samples	Mean	505	0.1	1.3	1.4	0.3	3.2	39.9
	Max	7300	0.3	3.2	3	0.6	6.7	82.3
	Min	0.0	0.0	0.0	0.6	0.0	0.0	2.3
	Median	96.	0.1	1.4	1.4	0.3	3.0	36.3
	SD	1374	0.07	0.72	0.5	0.2	1.4	23.1
Geometric Mean/Screening Level		126	0.33	1.0		0.7	1.95	14.1

Source: Clean Rivers Program and SWQMs

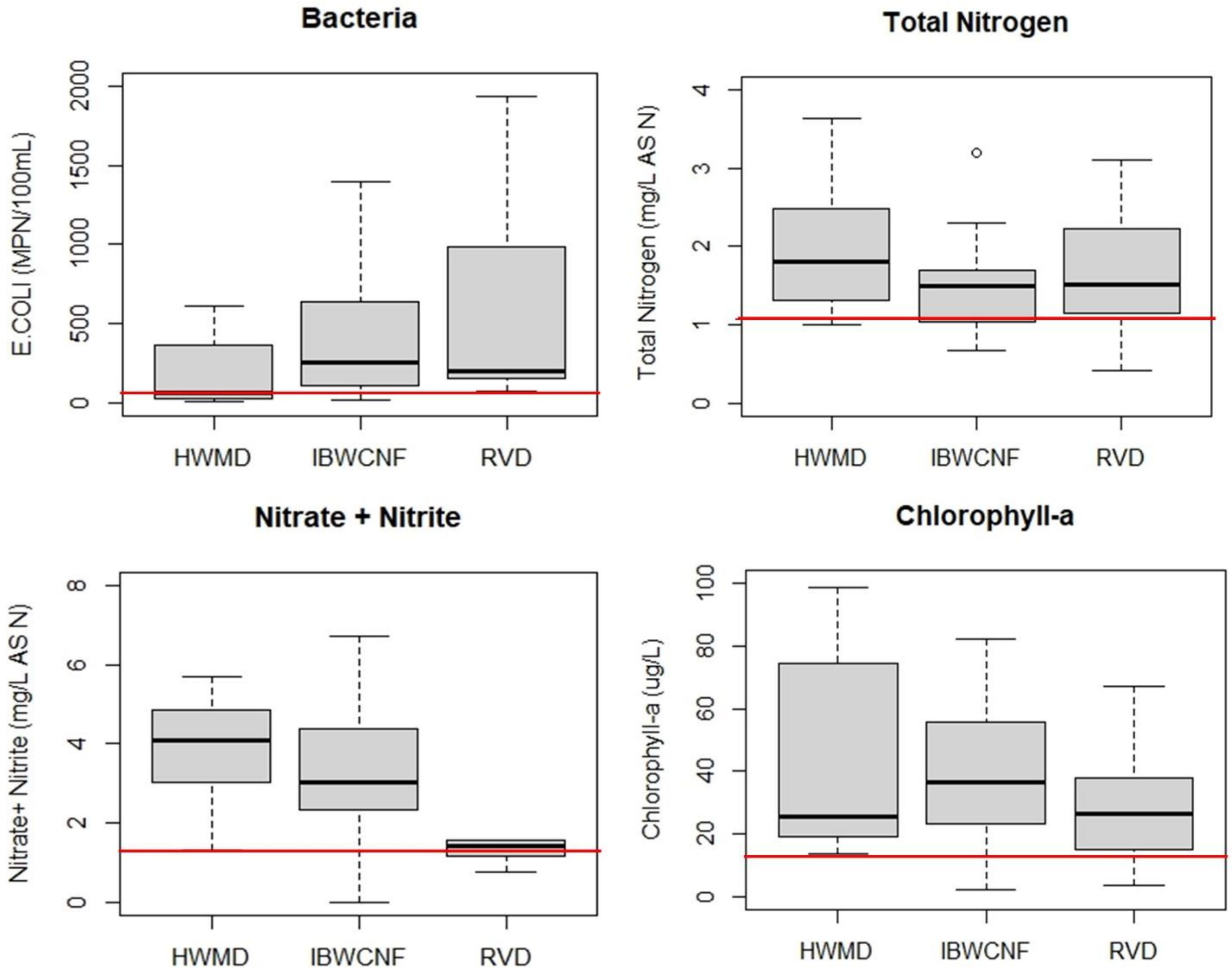


Figure 14: Predominant Concentration Levels for Bacteria, Ammonia, Total Nitrogen, and Chlorophyll-a

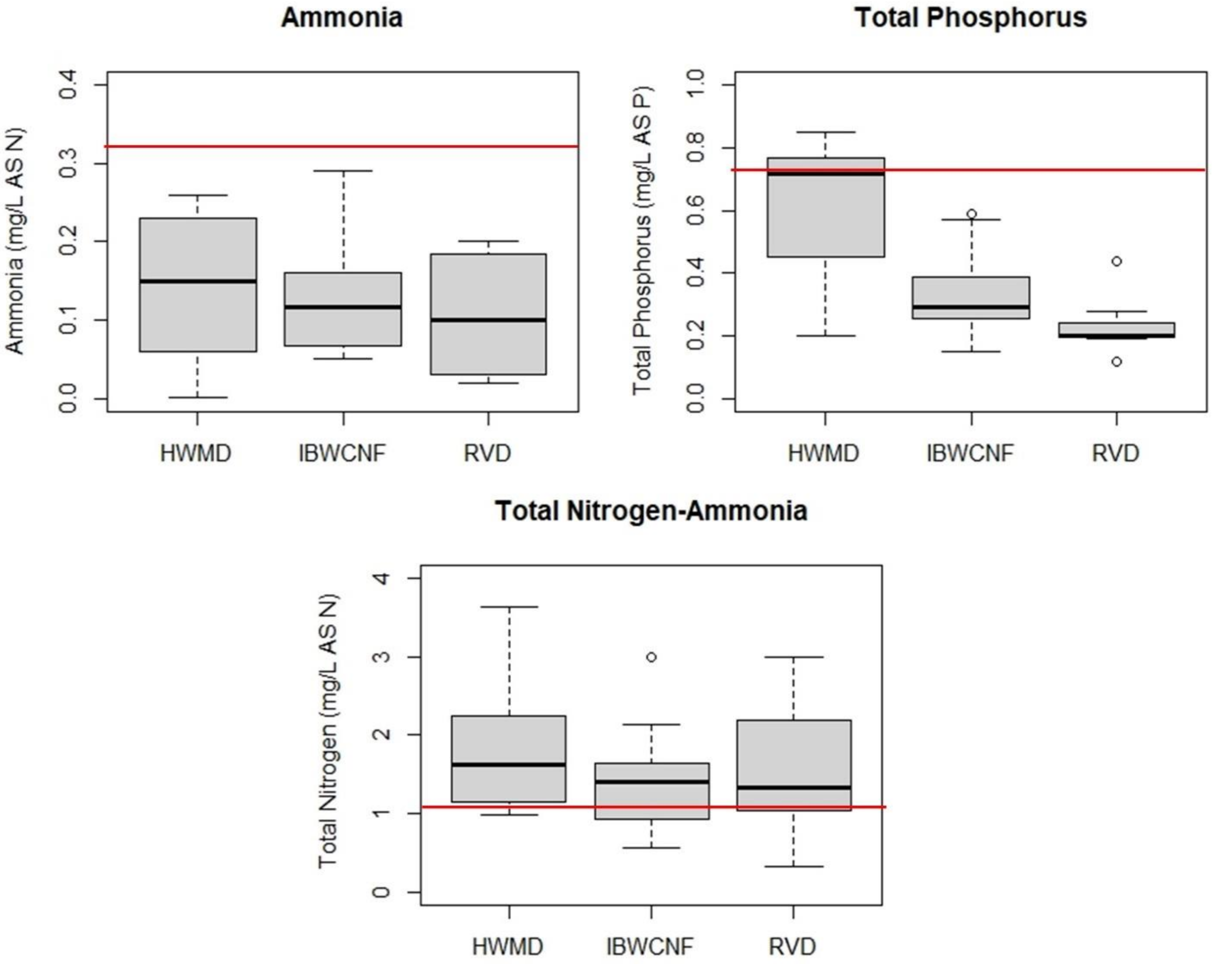


Figure 15: Concentrations Levels for Ammonia and Total Phosphorus.

Flow Data

Waterbody monitoring data is used to portray historical data that would represent most conditions of the study area. Flow data encompassed the volumetric flow rate for each waterway recorded from each station available. HWMD flow data reflects high flow values in 2019 with a mean value of 12 CMS. In 2018, the mean value was below 10 CMS. This reflects high correlation with flooding patterns with respect to sudden storm events. There is limited data for this watershed since its only available for three years. Among three watersheds, it has been determined that HWMD has the highest flow values that can potentially affect the load concentrations even if the water quality concentrations are low. The RVD flow data illustrate high flow values in 2018 of almost 10 CMS and in 2017 there was the highest flow value This reflects high correlation with flooding patterns with respect to sudden storm events. In June 2018, there was a severe storm event that caused in between 381mm to 508 mm of rainfall throughout the study area.

The IBWCNF watershed has two stations Mercedes and Sebastian. However, only the flow values utilized for further analysis were the ones from Sebastian since the water quality samples were obtained near that station. This would represent a better overview of the IBWCNF watershed behavior with respect to load concentrations. In 2017 and 2018, flow data was measured more than 10 CMS. Although the outliers were neglected, the flow values throughout 2012 to 2020 it seems to have mean values below 5 CMS which suggest a constant uniform flow for this watershed.

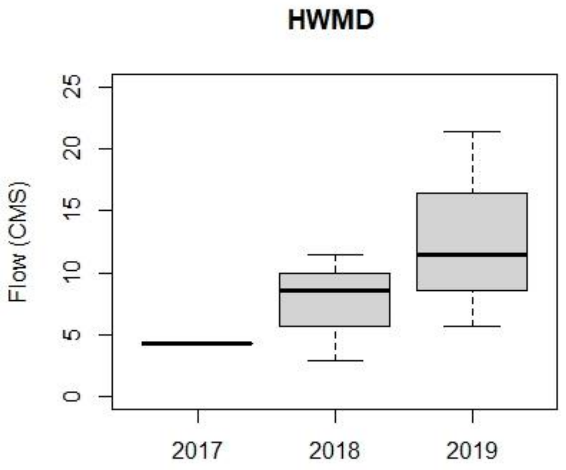


Figure 16: HWMD Flow Data

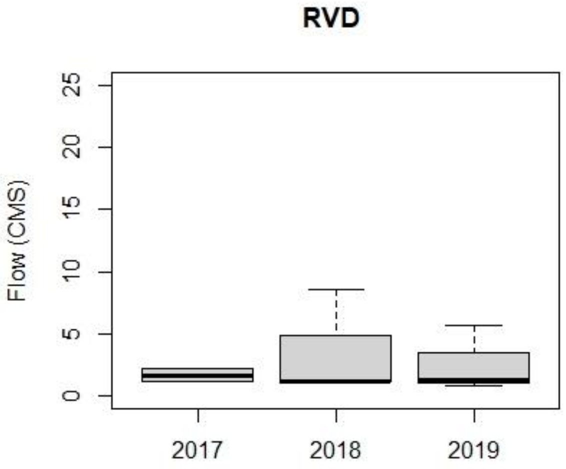


Figure 17: RVD Flow Data

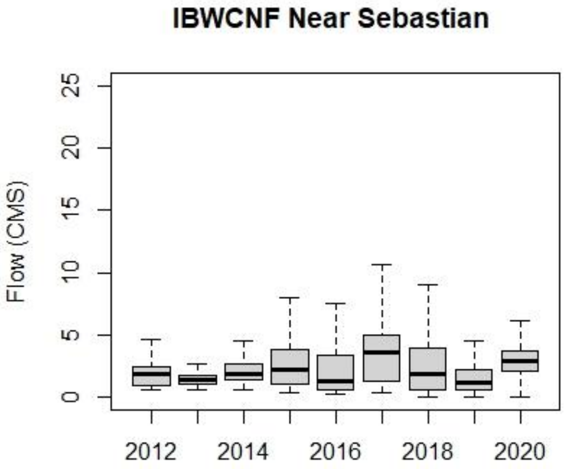


Figure 18: IBWCNF Flow Data

The following hydrographs represent the flooding events for June 2018 for the Mercedes and Sebastian stations in the IBWNF waterway see Figure 15. There is an impressive flow increase from the Sebastian station of almost 4,000 CMS. The difference between Mercedes and Sebastian stations in June 2018 is approximately 3,000 CMS. This suggest that there are some gates located near these stations that results in such sudden increase. In addition, to unforeseen storm events, the waterway is prone to carry significant amount of flow because of the diversion with the Arroyo Colorado waterways.

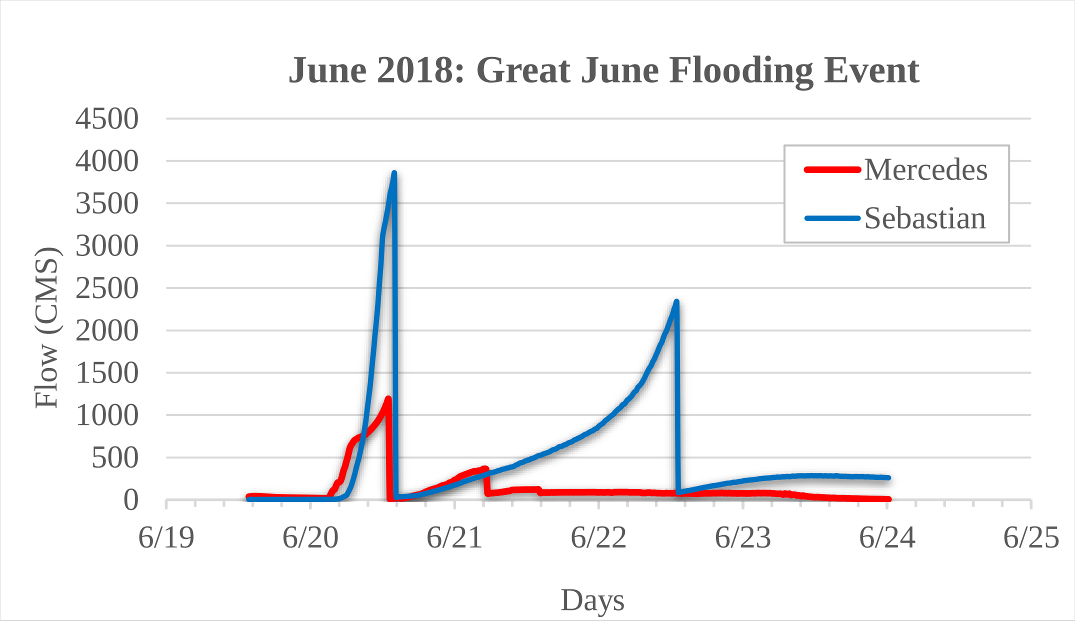


Figure 19: Flow data extracted from USIBWC to show big storm events

Monthly Flows

The Mercedes monthly flow was assessed by developing boxplots with the same dataset as the annual flow results. Figure 16 shows the flow with respect to the months between January (1) and November (11). The month of December was neglect ted since all the zero values were removed to facilitate the interpretation of the data. June (6), July (7), and October (10) were the months with higher variance in their flow values because in those months storm events are more likely to occur. In contrast, February (2), March (3), August (8), September (9) and November (9) are determined to have consistent flow values close to O CMS. June is the month with almost 50% higher flow values compared to the other months.

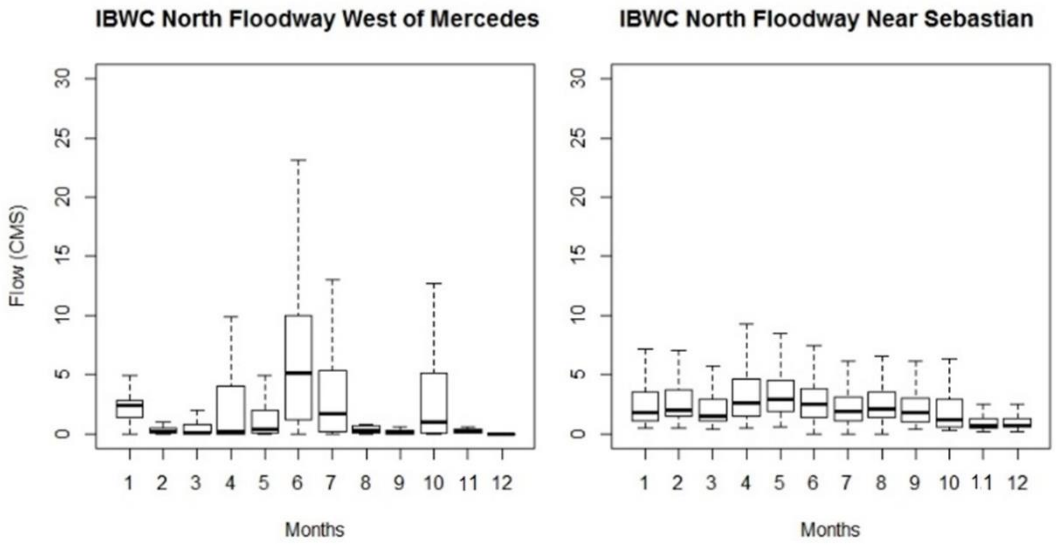


Figure 20: Mercedes and Sebastian Monthly Flow Boxplots

Annual Flows

Figure 17 shows a boxplot for the annual flow of Mercedes station from 2015 to 2020 to determine distributional characteristics of the sample data. In 2015, the annual mean flow varies much less than 2018 and 2020. In 2017, the annual mean flow is the lowest among the other years and the small size of the box corresponds to a high correlation between values. In 2018, the large box indicates that there were a wide variety of flow values especially at higher levels. Moreover, in 2019 the annual flows values presented the same mean as in 2015 which is close to 0 CMS and the overall flows values were close to each other. These boxplots show that in the years 2015, 2018 and 2020 showed a high variety of flow values which correspond to sudden rainfall events. The total maximum flow value was recorded in June 2018 with 1187.7 CMS.

Figure 17 shows the distribution of the Sebastian sample data. In 2012, the annual flow values were relatively consisted but not more than the flow values in 2013. Also, in 2012, 2014 and 2019 25% of the flow values were close to each other. The mean flow value for 2012 and 2014 close as well. In 2015 to 2018, 25% of the annual flow values had higher values. Overall, the mean values for all the years were near 2 CMS.

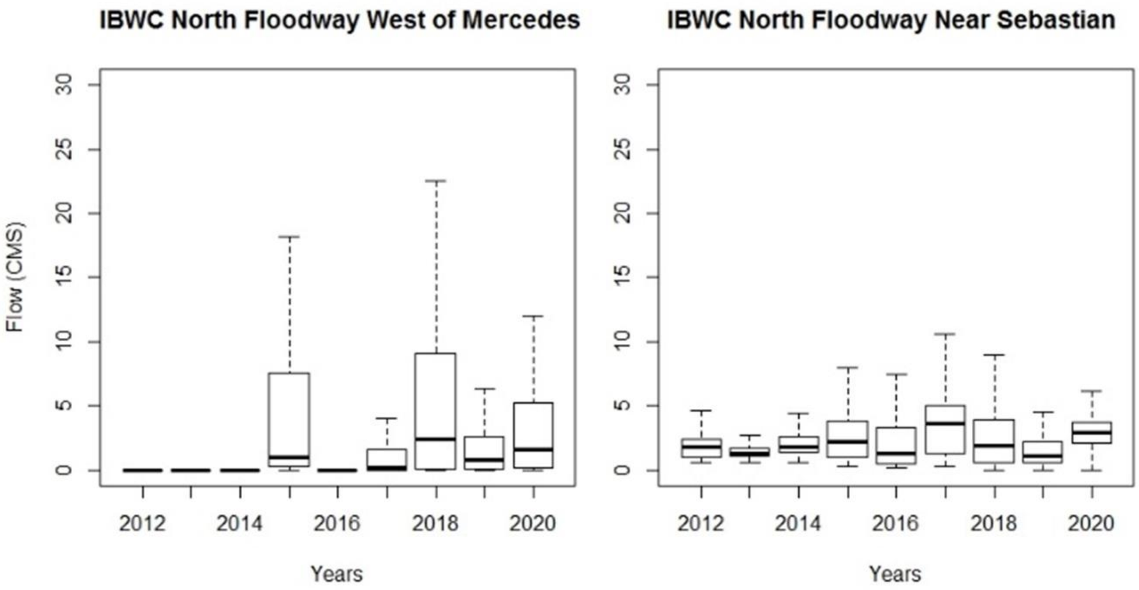


Figure 21: Mercedes and Sebastian Annual Flow Boxplots

Loading Concentrations

Loading concentrations were obtained from quantifying flow and water quality data. To well represent the loadings with each respected watershed, the loading concentration was based on the watershed area for the three watersheds. Table 9 shows the results for the unit area loading rates for each watershed reflecting which of the three watershed has the highest loading. HWMD watershed shows to have higher results with respect to the flow, water quality parameters and the overall watershed area where both NPS and PS are potential attributes to these elevated results. This data is not representative for the whole profile of the watersheds.

More data should be quantified in order to better distinguish which watershed contributes the most to water impairments to the LLM.

Table 11: Unit Area Loading Rates

Water Quality Parameters		HWMD	RVD	IBWCNF
Bacteria (Log E.Coli)	MPN/km^2/year	12.84	12.27	12.39
Ammonia	kg/km^2/year	120.68	30.77	47.72
TKN		1,586.32	669.73	477.14
TKN-Ammonia		1,465.64	638.96	429.42
TP		518.85	63.29	122.67
Nitrite +Nitrate		2,950.04	581.46	1,512.10
Chlorophyll-a		31.60	9.87	13.24

The unit area loadings distribution for each water quality were provided with respect to each watershed area. Bacteria unit area loading concentrations were determined to be high for IWBCNF watershed and the mean values high for RVD watershed this support the high quantities for NPS and PS such as OSSFS and STLR (ranches in these watersheds. TKN results show to be higher for HWMD which support the relative contribution of TLPA to this watershed. Nitrate and Nitrite and Chlorophyll-a concentrations were high in HWMD corresponding to the significant presence of urban area in the watershed. Ammonia results showed to be higher in IBWCNF watershed supporting the identification of substantial percent of agricultural lands. HWMD had the highest loadings for TP and Organic Nitrogen supporting the presence of MSWs. Figures 23 to 29 reflect the loading with respect to the subwatersheds of the three North and Central Watersheds. HWMD watershed was identified to be higher in all the water quality parameters due to the high flow recordings in this watershed

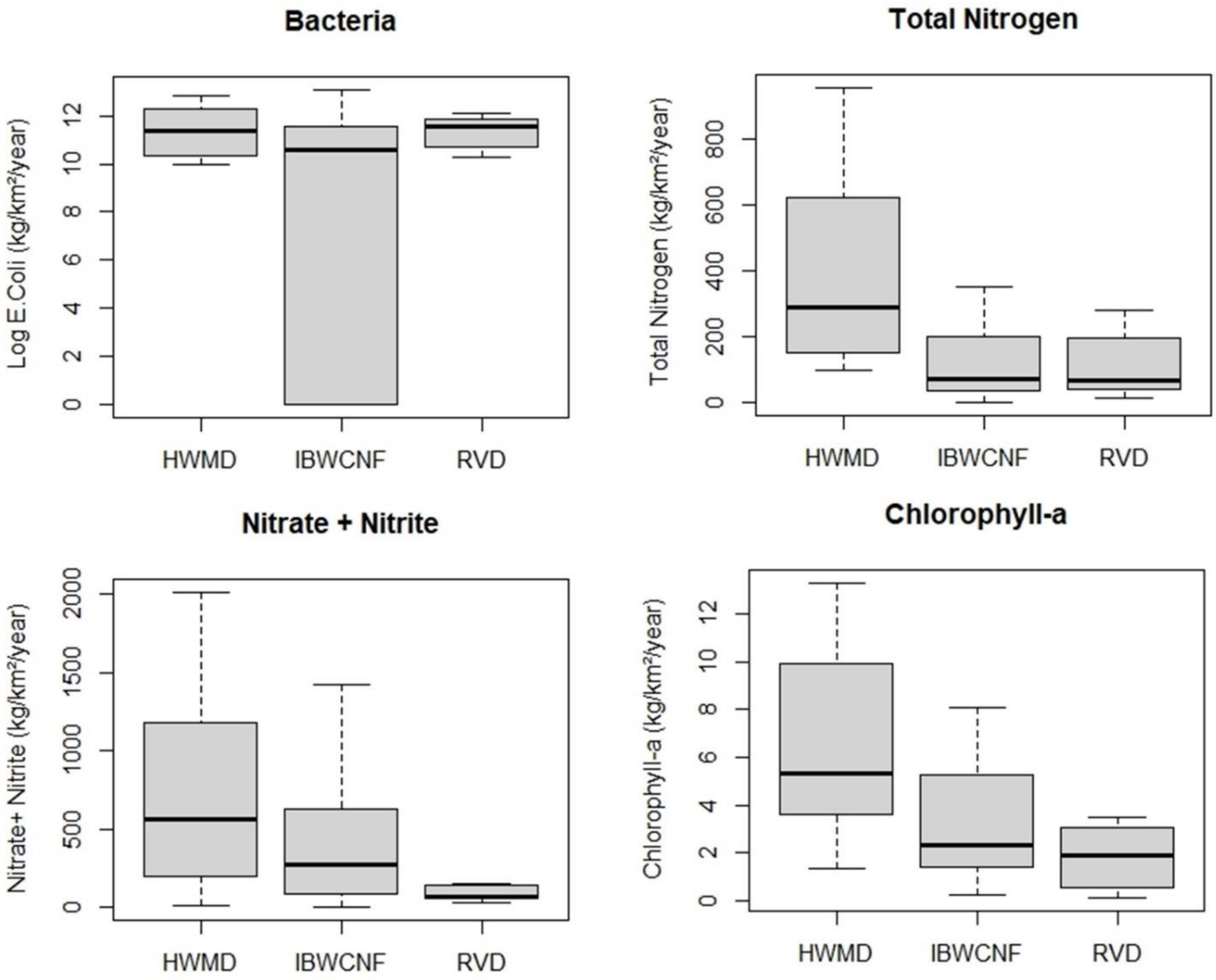


Figure 22: Unit Area Loading Rates for Bacteria, TKN, Nitrate+Nitrite, and Chlorophyll-a

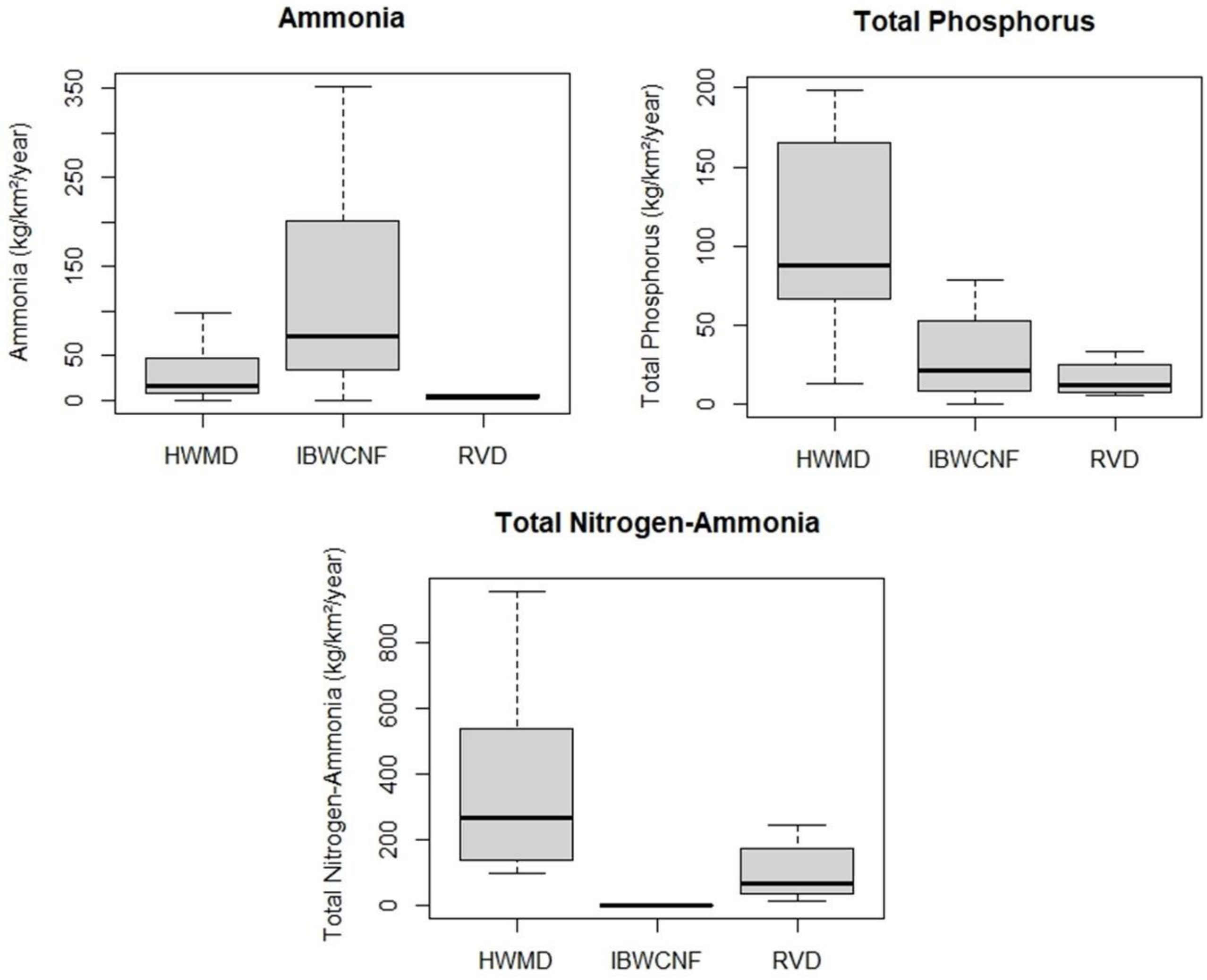
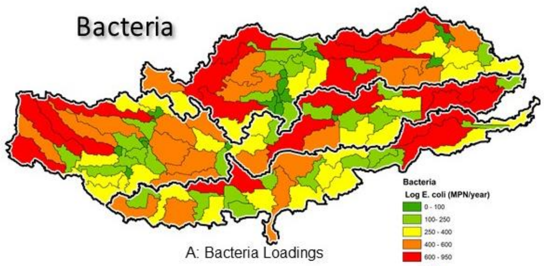
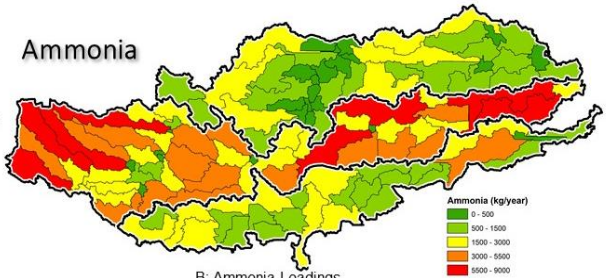


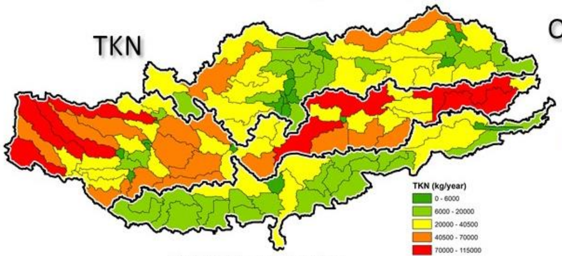
Figure 23: Unit Area Loading Rates for Ammonia and Phosphorus



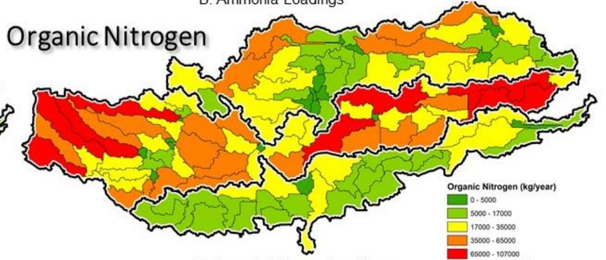
A: Bacteria Loadings



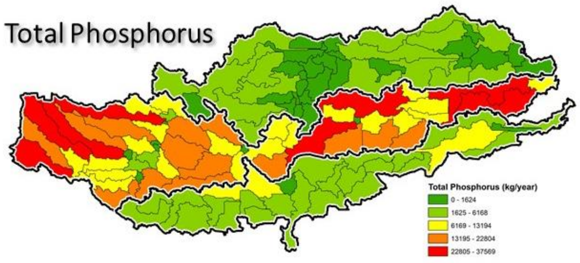
B: Ammonia Loadings



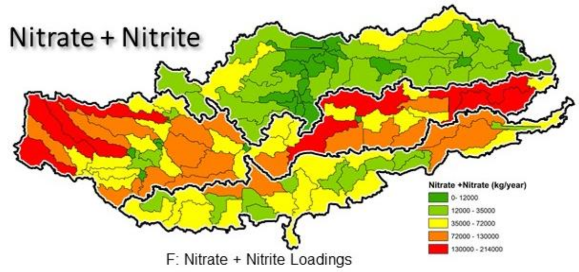
C: Total Nitrogen Loadings



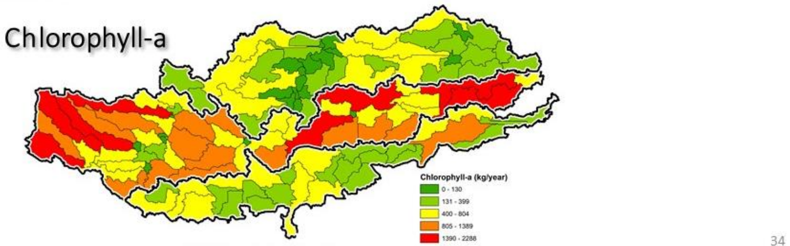
D: Organic Nitrogen Loadings



E: Total Phosphorus Loadings



F: Nitrate + Nitrite Loadings



G: Chlorophyll-a Loadings

Figure 24: Subwatershed Loading Concentration

CHAPTER IV

DISCUSSION AND CONCLUSION

The cyberinfrastructure, REON site, contributed significantly to this study in portraying relevant characteristics of each North and Central watersheds. This platform provided an efficient watershed characterization by exposing significant guidelines from EPA watershed characterization manual. This manual provides the basis to meet water quality and watershed management goals. Physical and natural features, land use, water body conditions, pollutant sources and waterbody monitoring data are the data needed to characterize a watershed. (EPA, 2013). The cyberinfrastructure gathers existing watershed boundaries, hydrology, land use, NPS, PS, water quality stations and flow stations to support the overview of the watershed characteristics. The REON site not only collect distinct information into one single source but also allows the stakeholders within each watershed to assess the watershed characteristics. Therefore, this platform is an innovative tool that support an effective watershed characterization.

Arc-GIS automated hydrology tools has shown to have satisfactory results in delineating watersheds. Elevation reconditioning has revealed improve results in areas with very flat terrains. Previous studies had positive results with respect to their watershed delineation by performing this methodology. Burning the waterways to the elevation data has enhanced the terrain to better support the current conditions of the elevation changes in the waterways. Generally, all the waterways within the area are man-made which is challenging for the elevation data to capture the waterways. The only major difference between Method 1 and Method 2 is the processing of LIDAR elevation data. Overall, the study can determine that the method 2 watershed delineation is acceptable to characterize the North and Central Watersheds.

Additional data could enhance the characterization but one of the limitations was the acquisition of flow data for the HWMD and the RVD watersheds. Flow data is essential for determining the load concentrations and have a better overview of the North and Central watersheds potential sources of pollution.

Watershed Characterization

Although the HWMD watershed was not the higher regarding the urban areas, it is considered higher in this NPS with respect to entire area of the North and Central watersheds. The HWMD had 20.3% of urban areas and 8.8% from the three watersheds. In contrast, IBWCNF presented a higher percent of 24.3% in urban areas, but it only had 5.8% with respect to the overall area of the North and Central watersheds. Urban areas have more impact on the HWMD in comparison to the other watersheds regarding the overall watershed areas. The identification of McAllen-Edinburg-Mission MSA in this watershed demonstrates the high presence of urban areas. This suggest that urban areas in this watershed are linked to the presence of bacteria and chlorophyll-a. Based on the water quality data obtained, only chlorophyll-a levels were higher than the other watershed levels. The high levels of chlorophyll-a relate to the HWMD watershed extensive urban areas.

Based on the total PS found in the North and Central watersheds, HWMD is the watershed to contribute 3.66 ratio with respect to the watershed area. While this watershed has greater PS among the watersheds is not particularly the most affected watershed with respect to the drainage area. The contributing PS identified in this watershed were TLAP and MSW. TLPA corresponds to the presence of high levels of nitrogen in the watershed and MSW corresponds to the presence of high total phosphorus levels. The load concentrations endorse NPS, PS and water quality concentrations since, bacteria, total nitrogen, nitrate and nitrite, chlorophyll-a, ammonia, total phosphorus and organic nitrogen had significant values in this watershed compared to the other watersheds. The high load concentrations in this watershed correspond to high flow values recorded. Therefore, more flow data is needed to further support this characterization and make the proper connections between sources of pollution and load concentrations.

RVD watershed had the higher percent of 20.3% for ranches and was identified to be higher regarding the total area of the North and Central watersheds as well. The water quality parameters associated with the presence of ranches are bacteria, ammonia, TP, and nitrite and nitrate. The results showed that RVD watershed have greater bacteria levels in comparison to the other watersheds which suggest ranches and the activities within these areas are causing high levels of bacteria. Bacteria loadings were the only loading concentrations in this watershed to be significant. Bacteria load concentration mean value correspond to almost 12 MPN/km2/year.

IBWCNF watershed was identified to have higher crop areas with 58.5% regarding the area as well as the overall area of the three watersheds which suggest the presence of significant agricultural activities. Therefore, it was determined that agricultural runoff is prone to release higher levels of ammonia where this watershed was limited to carry high ammonia levels. This indicates a possible change in land cover from 2016 to 2020. Also, not only ammonia is present in agricultural areas, but bacteria, TKN, TP, nitrite and nitrate, and chlorophyll-a. The IBWCNF watershed shows to have greater presence of nutrient water impairments because of the high agricultural area. This suggests the high levels of nitrite and nitrate in this watershed correspond to agricultural lands. This watershed had the higher contribution of PS such as: WWO, OSSFs, MS4s and Colonias among the watersheds. The sources identified contribute to the high levels of water quality concentrations identified. Only ammonia and nitrate and nitrite where these supports the presence of WWO, MS4s and colonias. The load concentration results showed IBWCNF to have high bacteria and ammonia loads. This suggests the presence of significant contribution of OSSFs is linked to bacteria loadings.

To uncover which North and Central watershed contributed the most to the LLM watershed, a cyberinfrastructure was established along with an ample watershed delineation. Then NPS, PS, water quality concentrations, flow data, and loading concentrations were evaluated for the identification watershed unique characteristics. HWMD and IBWCNF were the watersheds to contribute the most in water impairments to LLM watershed. They were found to have significant loadings of water quality parameters as well as NPS and PS contributions. Urban areas, TLPA and MSW were related to the high contribution of chlorophyll-a, TKN and TP. OSSFs and colonias were linked to major influence bacteria concentrations and loadings in which IBWCNF watershed possess the utmost. All these results can help stakeholders from the region along with the cyberinfrastructure which is a user-friendly website to identified all the characteristics of watersheds and mitigate the sources of pollution. This study is essential to help bring awareness to the local communities that reside within these watersheds specially for the people that visit the LLM watershed.

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APPENDIX

Table A.1: Hidalgo Willacy Main Drain Wastewater Outfalls

Hidalgo Willacy Main Drain		
	PERMIT NUM	PERMITTEE
1	13523-014	LA JOYA ISD
2	04040-000	CALPINE CONSTRUCTION FINANCE CO LP & CALPINE OPERATING SERVICES CO INC
3	10503-002	CITY OF EDINBURG
4	04138-000	CALPINE HIDALGO ENERGY CEN; CALPINE OP SERV CO; BROWNSVILLE PUB
5	10503-002	CITY OF EDINBURG
6	10633-004	CITY OF MCALLEN
7	13742-001	SEBASTIAN MUD
8	11510-002	CITY OF ELSA
9	04782-000	NORTH ALAMO WSC
10	14919-001	CITY OF EDCOUCH
11	00847719	CITY OF LYFORD

Table A.2 : Raymondville Drain Wastewater Outfalls

Raymondville Drain		
	PERMIT NUM	PERMITTEE
1	04480-000	NORTH ALAMO WSC
2	13747-001	NORTH ALAMO WSC
3	13747-004	NORTH ALAMO WSC
4	10365-001	CITY OF RAYMONDVILLE
5	05251-000	CITY OF RAYMONDVILLE

Table A.3 : IBWC North Floodway Wastewater Outfalls

IBWC North Floodway		
	PERMIT NUM	PERMITTEE
1	10619-001	CITY OF WESLACO
2	10619-003	CITY OF WESLACO
3	10330-001	CITY OF SANTA ROSA
4	15513-001	NORTH ALAMO WSC
5	14781-002	CITY OF LA VILLA
6	04758-000	PEN JOINT TENANTS AND NORTH CAMERON RWSC
7	01752-000	RIO GRANDE VALLEY SUGAR GROWERS INC

Table A.4 Hidalgo Willacy Main Drain Wastewater Landfills

Hidalgo Willacy Main Drain		
	NAME	FACILITY
1	CITY OF MCALLEN LANDFILL	POST CLOSED
2	HIDALGO COUNTY SHREDDER--GRINDER FACILITY	NOT CONSTRUCTED
3	HIDALGO COUNTY	CLOSED
4	CITY OF MISSION LANDFILL	CLOSED
5	CITY OF WESLACO LANDFILL	INACTIVE
6	WILLACY COUNTY LANDFILL	POST CLOSED
7	GREASE SPECIALIST LIQUID WASTE PROCESSING FACILITY	NOT CONSTRUCTED
8	CITY OF MCALLEN	NOT CONSTRUCTED
9	HIDALGO COUNTY LANDFILL	INACTIVE
10	RUBENS VACUUM & HYDROJETTING LIQUID WASTE PROCESSING FACILITY	INACTIVE
11	MLB EDINBURG LIQUID TRANSFER STATION	INACTIVE
12	CITY OF EDINBURG	CLOSED
13	CITY OF LYFORD LANDFILL	CLOSED

Table A.5: Raymondville Drain Wastewater Landfills

Raymondville Drain		
	NAME	FACILITY
1	HIDALGO COUNTY	NOT CONSTRUCTED
2	WILLACY COUNTY SOLID WASTE LANDFILL	NOT CONSTRUCTED
3	RECYCLING CONSULTANT SERCVICES	ACTIVE
4	UNION Y DIGNIDAD LANDFILL	CLOSED
5	CITY OF EDINBURG LANDFILL	NOT CONSTRUCTED
6	CITY OF MERCEDES TRANSFER STATION FACILITY	NOT CONSTRUCTED
7	CITY OF EDINBURG LANDFILL	ACTIVE
8	CITY OF RAYMONDVILLE LANDFILL	POST CLOSED

Table A.6 : IBWC North Floodway Wastewater Landfills

IBWC North Floodway		
	NAME	FACILITY
1	CITY OF WESLACO LANDFILL	CLOSED

Table A.7: Monthly Flow Data Summaries

	West Mercedes				Near Sebastian			
Data Range	2012-2020				2012-2020			
Observations	135, 542				304, 977			
Month	Mean	Min	Max	Median	Mean	Min	Max	Median
January	2.27	0.00	6.26	2.35	2.41	0.46	16.74	1.83
February	0.70	0.00	6.01	0.21	2.67	0.47	10.15	1.99
March	0.86	0.00	89.49	0.10	2.85	0.41	235.52	1.49
April	2.28	0.00	44.25	0.22	3.23	0.44	17.23	2.63
May	1.17	0.00	8.23	0.39	4.03	0.59	135.42	2.93
June	21.86	0.00	1187.66	5.17	14.17	0.00	3852.96	2.47
July	3.30	0.00	15.21	1.67	28.32	0.00	8412.59	1.90
August	0.36	0.00	2.34	0.31	3.87	0.00	29.47	2.06
September	0.36	0.00	4.42	0.04	2.55	0.36	16.26	1.82
October	7.76	0.00	66.53	0.98	2.57	0.24	50.06	1.21
November	0.21	0.07	0.63	0.12	1.31	0.18	29.27	0.68
December	0.00	0.00	0.00	0.00	1.08	0.20	9.23	0.73

Source: USIBWC website

Table:3-2 Annual Flow Data Summaries

	West Mercedes				Near Sebastian			
Year	Mean	Min	Max	Median	Mean	Min	Max	Median
2012	0	0	0	0	1.85	0.57	8.84	1.79
2013	0	0	0	0	1.64	0.58	11.96	1.33
2014	0	0	0	0	2.4	0.55	10.33	1.82
2015	10.72	0	66.53	0.96	4.07	0.3	135.42	2.2
2016	1.83	0	29.49	0.15	2.06	0.18	14.62	1.27
2017	19.29	0	1187.66	2.41	3.75	0.32	235.52	3.63
2018	4.16	0	424.28	0.77	10.51	0	3852.96	1.86
2019	3.3	0	15.21	1.67	2.85	0	164.63	1.13
2020	10.72	0	66.53	0.96	27.62	0	8412.59	2.89

Source: USIBWC website

Table A.8: Mercedes Annual Mean Dataset

IBWCNF Mercedes Annual Mean Flow Data	
Date	CMS
1/1/2015	0.379763321
1/1/2016	0
1/1/2017	0.277815597
1/1/2018	2.453020878
1/1/2019	1.221470144
1/1/2020	0.008724787

Table A.9: Mercedes Annual Max Dataset

IBWCNF Mercedes Annual Max Flow Data	
Date	CMS
1/1/2015	66.532
1/1/2016	0
1/1/2017	29.488
1/1/2018	1187.659
1/1/2019	424.28
1/1/2020	15.212

Table A.10: Mercedes Monthly Mean Dataset

IBWCNF Mercedes Monthly Mean Flow Data	
Date	CMS
4/1/2015	0.000003
8/1/2015	0.036335
10/1/2015	4.431523
11/1/2015	0.015832
9/1/2017	0.050864
10/1/2017	0.730040
3/1/2018	0.295422
4/1/2018	0.000121
5/1/2018	0.000003
6/1/2018	25.457163
9/1/2018	0.000606
10/1/2018	0.081366
1/1/2019	0.783847
2/1/2019	0.433344
3/1/2019	0.269581
4/1/2019	1.506642
5/1/2019	0.978656
6/1/2019	10.869474
8/1/2019	0.000786
9/1/2019	0.000305
7/1/2020	0.078638

Table A.11: Mercedes Monthly Max Dataset

IBWCNF Mercedes Monthly Max Flow Data	
Date	CMS
4/1/2015	0.001
8/1/2015	0.798
10/1/2015	66.532
11/1/2015	0.626
9/1/2017	4.416
10/1/2017	29.488
3/1/2018	89.488
4/1/2018	0.006
5/1/2018	0.005
6/1/2018	1187.659
9/1/2018	0.143
10/1/2018	9.03
1/1/2019	6.262
2/1/2019	6.01
3/1/2019	22.102
4/1/2019	44.249
5/1/2019	8.226
6/1/2019	424.28

8/1/2019	2.34
9/1/2019	0.878
7/1/2020	15.212

Table A.12: Sebastian Annual Mean Dataset

IBWCNF Sebastian Annual Mean Flow Data	
Date	CMS
1/1/2012	1.853545709
1/1/2013	1.64018472
1/1/2014	2.404222475
1/1/2015	4.071965205
1/1/2016	2.059347752
1/1/2017	3.749904318
1/1/2018	10.50905489
1/1/2019	2.853023695

Table A.13: Sebastian Annual Max Dataset

IBWCNF Sebastian Annual Max Flow Data	
Date	CMS
1/1/2012	8.841
1/1/2013	11.962
1/1/2014	10.33
1/1/2015	135.421
1/1/2016	14.623
1/1/2017	235.523
1/1/2018	3852.955
1/1/2019	164.628
	8412.59

Table A.14: Sebastian Monthly Max Dataset

IBWCNF Sebastian Monthly Max Flow Data	
Date	CMS
1/1/2012	4.093
2/1/2012	4.859
3/1/2012	8.841
4/1/2012	4.857
5/1/2012	4.979
6/1/2012	3.183
7/1/2012	3.692
8/1/2012	2.797
9/1/2012	2.806
10/1/2012	5.353
11/1/2012	1.003
12/1/2012	0.859
1/1/2013	1.541
2/1/2013	1.953
3/1/2013	1.216
4/1/2013	5.16
5/1/2013	7.988
6/1/2013	3.614
7/1/2013	2.979
8/1/2013	3.635
9/1/2013	7.617
10/1/2013	2.462
11/1/2013	11.962

12/1/2013	6.541
1/1/2014	6.541
2/1/2014	2.026
3/1/2014	2.5
4/1/2014	3
5/1/2014	4.445
6/1/2014	3.453
7/1/2014	3.299
8/1/2014	5.102
9/1/2014	10.33
10/1/2014	6.541
11/1/2014	9.956
12/1/2014	9.228
1/1/2015	16.741
2/1/2015	4.027
3/1/2015	16.855
4/1/2015	17.228
5/1/2015	135.421
6/1/2015	18.09
7/1/2015	6.112
8/1/2015	27.069
9/1/2015	16.259
10/1/2015	50.058
11/1/2015	29.267
12/1/2015	1.971
1/1/2016	4.034
2/1/2016	4.29
3/1/2016	12.807
4/1/2016	6.515
5/1/2016	13.217
6/1/2016	11.712
7/1/2016	4.686
8/1/2016	14.623
9/1/2016	9.532
10/1/2016	0.6
11/1/2016	4.368
12/1/2016	2.626
1/1/2017	10.762
2/1/2017	7.562
3/1/2017	235.523
4/1/2017	8.733
5/1/2017	16.443
6/1/2017	8.99
7/1/2017	8.558
8/1/2017	7.266
9/1/2017	6.902
10/1/2017	8.25
11/1/2017	4.489
12/1/2017	3.309
1/1/2018	5.688
2/1/2018	10.149
3/1/2018	5.963
4/1/2018	7.78
5/1/2018	6.463
6/1/2018	3852.955
7/1/2018	4.167
8/1/2018	3.714
9/1/2018	15.017
10/1/2018	3.115
11/1/2018	0.824

12/1/2018	1.56
1/1/2019	6.512
2/1/2019	6.54
3/1/2019	5.504
4/1/2019	7.953
5/1/2019	4.164
6/1/2019	164.628
7/1/2019	33.66
8/1/2019	10.458
9/1/2019	7.996
10/1/2019	4.408
11/1/2019	6.242
12/1/2019	3.502
1/1/2020	3.782
2/1/2020	4.545
3/1/2020	5.912
4/1/2020	5.584
5/1/2020	7.92
6/1/2020	19.576
7/1/2020	8412.59
8/1/2020	29.472
9/1/2020	2.894
10/1/2020	2.894
11/1/2020	2.894

Table A.15: Sebastian Monthly Mean Dataset

IBWCNF Sebastian Monthly Mean Flow Data	
Date	CMS
1/1/2012	2.02740289
2/1/2012	3.020897731
3/1/2012	1.76131588
4/1/2012	1.961717976
5/1/2012	2.689133108
6/1/2012	2.556851513
7/1/2012	2.275675237
8/1/2012	2.084891574
9/1/2012	1.50170625
10/1/2012	1.033675101
11/1/2012	0.736692254
12/1/2012	0.663114353
1/1/2013	0.839900571
2/1/2013	1.483316865
3/1/2013	0.893158532
4/1/2013	1.683935664
5/1/2013	1.885742945
6/1/2013	1.461047454
7/1/2013	1.343491743
8/1/2013	1.441226178
9/1/2013	3.018519834
10/1/2013	1.837949849
11/1/2013	2.196181252
12/1/2013	1.630258517
1/1/2014	2.420097301
2/1/2014	1.568461027
3/1/2014	1.412319533
4/1/2014	1.853850312
5/1/2014	2.589646309
6/1/2014	2.135571776

7/1/2014	1.904715729
8/1/2014	1.750061348
9/1/2014	5.046942957
10/1/2014	3.63469886
11/1/2014	2.474148907
12/1/2014	2.05501914
1/1/2015	2.34797379
2/1/2015	2.352173363
3/1/2015	5.550554772
4/1/2015	3.915702224
5/1/2015	10.12663138
6/1/2015	3.805440319
7/1/2015	2.352503024
8/1/2015	3.87776967
9/1/2015	2.4554125
10/1/2015	8.663968425
11/1/2015	2.075866435
12/1/2015	1.038026546
1/1/2016	0.988954637
2/1/2016	1.767099497
3/1/2016	1.687740255
4/1/2016	3.444958333
5/1/2016	4.20462836
6/1/2016	3.186446181
7/1/2016	2.82556922
8/1/2016	3.366549059
9/1/2016	1.769836572
10/1/2016	0.390949933
11/1/2016	0.444636364
12/1/2016	0.636858199
1/1/2017	2.767975806
2/1/2017	3.153190458
3/1/2017	7.860833725
4/1/2017	5.761921181
5/1/2017	5.754701826
6/1/2017	4.447475694
7/1/2017	5.371573554
8/1/2017	4.300611523
9/1/2017	1.868826761
10/1/2017	2.07687727
11/1/2017	0.686013889
12/1/2017	0.814162634
1/1/2018	3.921058468
2/1/2018	5.630433218
3/1/2018	2.495565736
4/1/2018	4.85872255
5/1/2018	3.864083659
6/1/2018	144.0308541
7/1/2018	1.270146268
8/1/2018	1.906449933
9/1/2018	2.99749606
10/1/2018	0.780062555
11/1/2018	0.584860353
12/1/2018	0.661415659
1/1/2019	4.258639543
2/1/2019	3.008759673
3/1/2019	1.058281629
4/1/2019	1.910559722
5/1/2019	2.007825269
6/1/2019	14.83705799

7/1/2019	0.705749832
8/1/2019	1.68481754
9/1/2019	1.450426736
10/1/2019	1.390422043
11/1/2019	1.041092014
12/1/2019	1.144411962
1/1/2020	2.124138777
2/1/2020	3.389125718
3/1/2020	2.911936156
4/1/2020	3.782814236
5/1/2020	3.102975437
6/1/2020	3.5954125
7/1/2020	236.7467189
8/1/2020	14.41914487
9/1/2020	2.894
10/1/2020	2.894
11/1/2020	2.894

Table A.16: HWMD Water Quality Dataset

Hidalgo Willacy Main Drain Water Quality							
Date	Bacteria MPN/100ML	Ammonia MG/L AS N	TKN (Total Nitrogen) MG/L AS N	TP (Total Phosphorus) MG/L AS P	Nitrite MG/L AS N	Nitrate MG/L AS N	Chlorophyll-a UG/L
10/4/2017	610	0.02	1	0.733	3.02	0	57
12/3/2017	10	0.26	2.85	0.847	3.87	0	13.5
5/1/2018	120	0.002	3.63	0.755	4.71	0	91.5
7/18/2018	20	0.2	2.1	0.2	1.2	0.099	98.5
10/31/2018	80	0.1	1.5	0.67	5.6	0.09	23.9
1/29/2019	31	0.1	1.21	0.7	5.6	0.06	19.3
4/2/2019	1400	0.2	1.4	0.78	4.02	0.06	27
7/16/2019	2200	0.26	2.1	0.23	0.03	0.02	19.3

Table A.17: RVD Water Quality Dataset

Raymondville Drain Water Quality							
Date	Bacteria MPN/100ML	Ammonia MG/L AS N	TKN (Total Nitrogen) MG/L AS N	TP (Total Phosphorus) MG/L AS P	Nitrite MG/L AS N	Nitrate MG/L AS N	Chlorophyll-a UG/L
10/4/2017	1940	0.02	1	0.28	1.17	0	36.3
12/3/2017	150	0.1	0.42	0.2	1.52	0	18
5/1/2018	220	0.02	2.75	0.12	2.34	0	33.3
7/18/2018	150	0.1	3.1	0.2	0.8	0.05	39.8

10/31/2018	1700	0.2	1.3	0.2	1.5	0.05	11.7
1/29/2019	74	0.17	1.43	0.2	5.6	0.06	3.8
4/2/2019	2400	0.04	1.7	0.44	1.34	0.08	67
7/16/2019	130	0.2	1.6	0.19	0.64	0.11	19.8

Table A.18: IBWCNF Water Quality Dataset

IBWC North Floodway Water Quality						
Date	Bacteria MPN/100ML	Ammonia MG/L AS N	TKN (Total Nitrogen) MG/L AS N	TP (Total Phosphorus) MG/L AS P	Nitrate+Nitrite MG/L AS N	Chlorophyll-a UG/L
11/3/2011	0	0.16	2.03	0.00	2.42	29.70
2/23/2012	0	0.09	0.95	0.21	5.28	35.00
5/3/2012	0	0.13	1.49	0.29	4.47	40.20
8/23/2012	0	0.12	1.04	0.23	2.26	55.70
11/19/2012	0	0.06	1.50	0.59	2.75	42.60
3/12/2013	110	0.16	1.08	0.00	2.68	40.50
8/21/2013	640	0.23	0.89	0.23	2.01	51.40
11/25/2013	7300	0.12	0.68	0.41	3.96	9.50
8/14/2014	0	0.06	1.70	0.00	2.03	82.30
11/24/2014	1100	0.11	1.36	0.34	3.82	44.40
2/25/2015	110	0.13	1.57	0.27	3.08	35.40
3/26/2015	0	0.25	1.66	0.35	6.71	26.00
8/26/2015	1400	0.12	1.84	0.32	3.10	60.20
8/27/2015	0	0.07	1.53	0.26	3.02	76.20
11/30/2015	610	0.19	3.19	0.25	4.98	23.40
5/4/2016	360	0.21	2.01	0.31	4.37	68.30
8/4/2016	0	0.00	0.00	0.27	2.08	20.10
11/2/2016	95	0.05	0.74	0.42	2.98	52.80
2/8/2017	0	0.08	1.72	0.39	4.29	11.00
5/3/2017	75	0.08	1.55	0.27	4.37	2.31
7/25/2017	120	0.05	0.00	0.25	1.07	19.60
11/29/2017	160	0.00	0.00	0.00	0.00	9.94
1/30/2018	20	0.16	0.00	0.29	3.80	6.91
4/18/2018	340	0.05	1.29	0.50	4.43	66.90
7/18/2018	96	0.05	2.30	0.39	2.36	78.10
10/16/2018	300	0.29	1.51	0.57	1.79	72.30
1/23/2019	200	0.10	1.03	0.35	4.67	28.60
4/16/2019	1600	0.05	1.03	0.24	2.65	36.30
11/7/2019	0	0.21	1.20	0.15	2.35	32.60

BIOGRAPHICAL SKETCH

Linda I. Navarro Navarro graduated with a B.S in Civil Engineering from the University of Texas Rio Grande Valley in Fall 2019. She has worked as an engineering and research intern for several local entities throughout the LRGV region such as the City of Weslaco, LRGV Development Council and RATES. Currently she is working as a Graduate Research Assistant (GRA) where she is collaborating with other state-wide entities such as TCEQ with her thesis results for the 319 Nonpoint Source Program North and Central Watershed Characterization Project. Linda was awarded her Master of Science in Civil Engineering, from the University of Texas Rio Grande Valley, in May of 2021. She can be contacted at linda.navarro028@gmail.com