Assessment and Improvement of Solid Waste Pollution Crisis:
Restoration of Panama's Juan Diaz River Watershed

Alexander Boucher Jr.
Kristen Soden
Sophie Chretien
Alexander Guerra

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An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute and sponsor, Marea Verde, in partial fulfillment of the requirements for the degree of Bachelor of Science

Date:
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Submitted By:
Alexander Boucher Jr.
Kristen Soden
Sophie Chretien
Alexander Guerra

Report Submitted to:
Professor James A. Chiarelli
Professor Jefferson A. Sphar
Worcester Polytechnic Institute

Mirei Endara de Heras
Marea Verde Panama

Abstract

The goal of this project was to characterize and provide information on the Juan Diaz Watershed in Panama for our sponsor organization Marea Verde. Marea Verde is a non-profit dedicated to cleaning up the environment and preserving the ecosystems within and surrounding Panama. The sponsor provided the team with high-resolution satellite images, communal ground-level photos, and a community outreach survey distributed to residents in the watershed. These batches of data were analyzed. The conclusion was that the infrastructure is nowhere near sufficient to support the current and future populations living in the communities on the river. The WPI team recommends that Marea Verde continue the unfinished work of characterizing the Juan Diaz Watershed with the basis that we have created from this preliminary data. Then present a proposal to the Panamanian government outlining all the issues in the watershed in hopes that they will fund a mass overhaul of resources and garbage collection infrastructure to mitigate this pollution issue for years to come.

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Executive Summary

The project outlined in this paper's goal was to learn more about the Juan Diaz River Watershed, which borders inside of 8 Panama's many rapidly developing districts. Our sponsor organization, Marea Verde, is a non-profit that advocates for the people of Panama facing these pollution crises and provides volunteer intervention efforts to clean up different areas of Panama. To complete this goal, we planned to go to Panama and visit the watershed and collect data that would allow us to supply Marea Verde with the information on the river communities they needed to help mitigate the solid waste issue. Unfortunately, the team was unable to travel due to travel restrictions regarding COVID-19. However, our sponsors provided data to analyze, and we provide them with conclusions and recommendations for these communities.

The first of this data is communal images from around the watershed. These images were analyzed by describing the aspects of the photo. They were uploaded to google earth with the description and color-coding to indicate the level of pollution seen in the photo. We hope this will assist Marea Verde in identifying some target areas to concentrate their solid waste mitigation efforts.

The second batch of data provided to us by our sponsor was satellite images that they had applied for and received from the Ministry of the Environment in Panama. These high-resolution images allowed the team to view ground-level overhead shots of the entire watershed. Which made mapping out the river and the different districts much more manageable and gave the team a better reference to the location we were working in remotely. Unfortunately, the ArcGIS work was incomplete due to various limitations described later in this paper. However, the information and base of the work are complete and will be completed in the future with more information.

The final set of data the Team received from Panama was a communal outreach survey, which was designed in part by the Marea Verde organization and the University of Miami, with a few questions added by our team to assist us in analysis and comparisons. The survey focused on five categories: Residential History, Waste Production, Garbage/Recycling Collection, River Knowledge/Habits, and Interest in further studies. The data was provided raw in an excel document in Spanish. The WPI team translated and compiled all the data to create graphics that depict the information and point towards some causes and possible solutions.

With this data, and the limited time the WPI team had to analyze it, we came up with an overarching conclusion about the pollution in the Juan Diaz Watershed and some future recommendations for our sponsor organization. The conclusion is that the watershed communities have been growing steadily for at least the past two decades. However, the infrastructure provided to them by local and Panamanian governments has not grown in parallel to support the population increase. The information uncovered by Marea Verde, once complete, should be presented to the Panamanian government to propose they fund the necessary resources and infrastructure construction to support the current and future generations living on the watershed. If the government fails, the watershed does not have many other options, with commercially packaged products being the norm in present society. The inhabitants have no choice of what to buy and nowhere to properly dispose of their waste, which they cannot and will not solve without the government's assistance.

Table of Contents

List of Figures

Table of Authorship

Section	Primary Author(s)	Primary Editor(s)
Abstract	Alexander Boucher Jr.	Alexander Boucher Jr.
Executive Summary	Alexander Boucher Jr.	Alexander Boucher Jr.
Section 1.1	Alexander Guerra	Alexander Guerra
Section 1.2	Sophie Chretien Kristen Soden	Alexander Guerra
Section 2.1	Alexander Guerra	Alexander Guerra
Section 2.2	Alexander Boucher Jr.	Sophie Chretien
Section 2.3	Alexander Guerra Kristen Soden	Alexander Boucher Jr.
Section 2.4	Alexander Boucher Jr.	Alexander Boucher Jr.
Section 3.1	Kristen Soden	Kristen Soden
Section 3.2	Sophie Chretien	Sophie Chretien Kristen Soden
Section 3.3	Alexander Boucher Jr.	Alexander Boucher Jr. Kristen Soden
Section 3.4	Sophie Chretien	Kristen Soden
Section 4.1	Kristen Soden	Kristen Soden
Section 4.2	Sophie Chretien	Sophie Chretien
Section 4.3	Alexander Boucher Jr.	Alexander Boucher Jr.
Section 5.1	Kristen Soden	Kristen Soden
Section 5.2	Sophie Chretien	Sophie Chretien
Section 5.3	Alexander Boucher Jr.	Alexander Boucher Jr.
Section 5.4	Alexander Boucher Jr.	Alexander Boucher Jr.

Abbreviations and Notations

JDR: Juan Diaz River
GIS: Geographic Information System
ESRI: Environmental Systems Research Institute
WPI: Worcester Polytechnic Institute
MHR: Matías Hernández River
ANCÓN: National Association for Nature Conservation
GDP: Gross Domestic Product
NAE: Nation Authority of the Environment
B.O.B.: Barrera O Basura (translated Barrier of Garbage)
DEM: Digital Elevation Model

Chapter 1: Introduction

1.1 - A Brief History of Plastics, Panama, and Pollution

1.1.1 - The Debut of Plastics

The years following World War II marked one of the most significant periods of industrial reform in the United States (Hendrix, 2011). The momentum created by the rapid expansion of the Cold War era military-industrial complex in addition to several important inventions, which comprised the 'Technological Revolution', drove an exponential increase in manufacturing capacity and created an associated demand for raw materials (Pruitt, 2020). This novel industry dynamic led to the widespread adoption of synthetic polymers such as PVC, PET, Teflon, and other plastics for their tremendous sustainability and durability (Niiler, 2019). The production and distribution of products containing such materials were allowed to develop unimpeded by any regulatory mechanisms for nearly 70 years and plastics rapidly achieved near ubiquity among all developed nations, with production increasing by 20,000% worldwide from 1950 to 2015 (Ritchie et al, 2018).

1.1.2 - Panama's Early Relationship with Plastic

Concurrent to this epoch of plastics, Panama began industrializing in the 1960s. Following the precedent of similarly developed nations, they assimilated plastics in just a couple decades. Since then, plastic has become an integral component of the Panamanian manufacturing industry, contributing to the country's economy by creating lucrative trading opportunities and

opening new sectors such as chemical products and plastics, which compose a combined ~9% of Panama's yearly exports (OEC, 2019). These developments influenced a period of accelerated economic growth during the late 1900s in which, according to the book *Panama: A Country Study*, the GDP increased from US$660 million at 9.2% industry with little manufacturing in 1965 to $US4,880 million at 17.7% industry with nearly 50% manufacturing in 1985 (Meditz et al, 1989). This period also marked a domestic shift towards the integration of plastic products for consumer use. While there is little data about plastic imports prior to 1994, data from *The Observatory for Economic Complexity* suggests that the import growth has historically mirrored the export growth within a ±5% margin. Should this trend be consistent along the past 30 years, it would suggest that the economic value of plastics as an export within Panama's manufacturing sector has increased proportionally to the domestic use of said plastics. While this implies that the manufacturing and integration of plastic products has yielded a net benefit for Panamanian society, the long-neglected environmental impact of unmanaged plastic use and disposal has contributed to a pollution crisis.

1.1.3 - The Evolution of Environmental Law

Panama's industrial growth and eager adoption of plastics quickly outpaced the capacity of their waste disposal system and of the surrounding environment. This became apparent in the late 20th century as the country's many river systems began to grow inundated with discarded household waste from communities along the watersheds. The Panamanian government was not equipped to deal with this issue, as it was still recoiling from the invasion of Panama in 1989 (operation *Just Cause*) and the forced impeachment of Manuel Noriega. This is due to the

fragmented internal state of Panama, the pollution of the rivers would persist for nearly a decade (O'Neil, 2014).

In 1994, the government managed to re-establish itself (as a representative democracy) and stabilize the GDP after it fell 13% in the couple years prior to the invasion. These infrastructural reforms allowed the country to orient itself towards more nuanced legislation, notably those which concerned the environment, to further develop Panama in a sustainable manner. The first environmental component of this legislation was ratified in 1998 marked and named "Law 41: The General of the Environment of the Republic of Panama". This law established discrete standards of environmental protection in addition to civic responsibilities, legal capacities of the government, and the National Authority of the Environment which would oversee these things. Though these reforms saw minimal changes in the growing rate of pollution, the law established an important precedent which would facilitate numerous improvements in environmental management over the next two decades and into the present day. The year 2015 marked perhaps the most pivotal development in Panamanian environmental law, as several reforms were made which embellished upon previous policies. One of the most important of such changes was increasing the rank of the National Authority of the Environment to that of a ministry. In addition to extending the legal capabilities of the NAE, this elevated the symbolic importance of its mission to one of international concern. In the following years, the frequency of legal action increased dramatically, with laws being passed in 2018, 2020, and 2021 (see **Appendix A** for Original Copies of Law and **Appendix B** for Translated Law Copies referenced in this paper). Despite the radical changes these new laws will introduce such as the banning of plastic bags, it has become clear that the government still needs to further tighten its

regulation on the disposal of waste, particularly plastics, to fully rehabilitate the environment and prevent any future damage from occurring.

1.2 - Modern Pollution Struggle

Certain areas have shown themselves to be in particularly dire need of intervention. These areas consist primarily of new informal settlements strewn about the watersheds, most of which are located within a few kilometers of the nearest river. Many of these residencies reside in partial isolation from core civil services, particularly waste collection, and disposal, and are forced to seek unsustainable alternatives. There is a large discrepancy between the sophistication of the waste collection services and the modern plastic goods accessible to the citizens. This has led many inhabitants of the settlements to throw their trash in the river. The trash tends to build up in the river's bends, causing clogging, or the waste gets carried through the river into other bodies of water leading to the ocean. The build-up and spread cause contamination throughout the river and connecting bays, which has led to the waterways becoming too polluted to use for fishing or swimming.

The Juan Diaz River is one such river in which the accumulation of plastic and other solid wastes has reached dangerous levels. With the crucial role it plays in the ecosystem, it has become the focal point of one of several environmental organizations in Panama, Marea Verde. Marea Verde is a non-profit organization based in Panama City that has dedicated its work to combat the escalating solid waste pollution contaminating the coasts and rivers in Panama (Marea Verde, n.d.). They have previously developed and implemented a waste collection system denoted Barrera O Basura or "B.o.B." (translated Barrier of Garbage) on prominent rivers in Panama, such as the Matías Hernández River, that traverses Panama City. The garbage

collection efforts are paired with awareness programs taught at primary schools, called “Green Classrooms,” that aid in the education of sustainable practices and keeping the environment clean. These programs constitute a large-scale social engineering effort orchestrated by Marea Verde, which seeks to promote proper waste disposal and prevent further pollution.

Through an extensive analysis of the pollution content of the river, Marea Verde has found that nearly 75% of the waste in the Juan Diaz River is plastic based (Marea Verde, n.d.). This statistic coincides with a statement from the executive director of the National Association for Nature Conservation (ANCÓN) Rita Spadafore, that nearly 80% of the 480 tons of trash produced each day by Panama City and San Miguelito is plastic (Spadafore, 2018).

Our team worked with Marea Verde to assist their association with achieving their goals in the Juan Diaz watershed. In this project, we analyzed community survey results of those living in the river’s watershed, used satellite images to create a map of the area to determine qualified population samples, and developed an interactive map compiled with ground level images to locate areas in need of assistance. Surveys were distributed to the community members to collect information regarding their knowledge about pollution in the river, sustainable practices they currently employ, and general relationship with the river. The team utilized a software program called ArcGIS to combine satellite images to generate a high-resolution satellite map of the region surrounding the river. Ground level images were pinpointed in Google Earth to create a map with the goal of understanding waste accumulation. We analyzed the collected information and created conclusions based off our findings to dictate the type of approach used to keep the community educated about solid waste pollution and suggest potential pollution prevention methods.

Chapter 2: Background

The waterways of Panama are essential to sustain the country's people and its economy. Solid waste pollution is becoming a noticeable threat to both, causing the government and private organizations to take action in the clean-up of Panamanian watersheds. Rectifying the pollution in these areas will stabilize the socioeconomic issue that Panama experiences when the rivers providing water to many different industrial and communal sectors become clogged with solid waste (Linowes & Hupert, 2006). In this chapter, we first discuss the Juan Diaz River's geographical location and features, the pollutants within it, and why solid waste pollution enters the river. Second, we will introduce the sponsor's organization and their ongoing efforts addressing the pollution crisis, Marea Verde, and their goals, outreach, and accomplishments that this project can build upon. A section focused upon the data collection methods that Marea Verde plans to use to gather information about the JDR will follow. Finally, we will concentrate on the potential impact that this project will make on the environment, river basin communities, and Panama as a whole.

2.1 - The Juan Diaz River

The Juan Diaz River is a 28km long river located in the southeast of Panama that begins in Cerro Azul, at an elevation of ~700m above sea level, and ends in the Panama Bay Area. Its main tributaries are: Las Lajas, María Prieta, Naranjal, Palomo, la Quebrada Espavé y la Quebrada Malagueto. It is located within the Panama and San Miguelito districts in Panama, and the counties located on the river from these districts are: Juan Diaz, Rufina Alfaro, Pedregal, Arnulfo Arias, Jose Domingo Espinar, Ernesto Cordoba Campos, and Belisario Frias. The river

basin has a drainage area of 149.97km^2 and the topography has an average slope of 12.8% (Alonso, 2017).

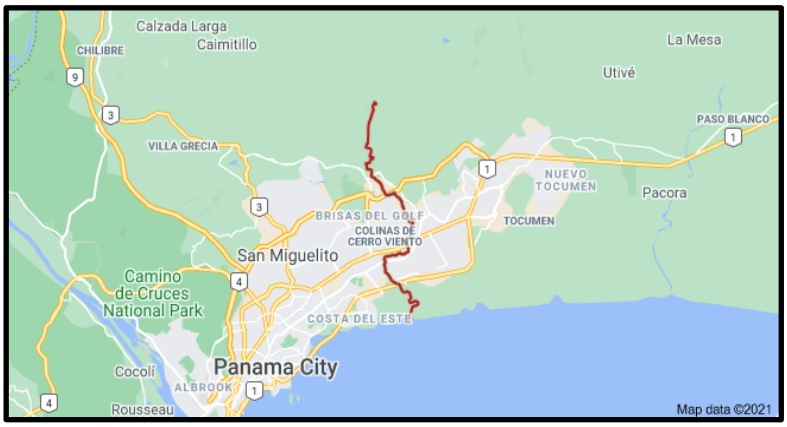

Figure 2.1a: Map of Panama City with JDR highlighted. (Google Maps)

2.1.2 - Urbanization and Pollution in Panama

During the last few decades, urban development in the river basin has increased significantly, from 10% in the mid-1990s to an estimated 30% today (Castro-Gómez, 2012). The unplanned urbanization of land in Panama has tangentially amplified the preexisting influx of solid waste pollution by increasing the population around the river, thereby overburdening the meager waste disposal services, and encouraging citizens to discard garbage into the river (Mingorance et al., 2016). The saturation of the river with non-biodegradable solids threatens to impact both the hydrological properties of the river and the surrounding organisms and communities. Honingh et al (2020) states that:

Plastic pollution in aquatic environments is an emerging hazard because of its direct and indirect negative effects on ecosystem health and human livelihood. Direct effects include the entanglement or ingestion by animals or damage to vessels. Longer-term effects include break

down into microplastics and negative impacts on mangrove forests. Land-based plastic waste may enter rivers and urban drainage systems through natural drivers, such as wind and surface runoff, or direct dumping. Once in the water system, plastic pollution accumulates at hydraulic infrastructures (such as rack structures), leading to clogging of the urban drainage system. In turn, this may lead to increased flood risk in urban areas.

In isolation of human influence, rivers are self-regulatory, able to maintain a structural and hydraulic equilibrium despite the effects of floods, storms, and other natural disasters. Through the mechanisms with which this equilibrium is maintained, rivers can participate in commensal/symbiotic relationships with surrounding communities and ecosystems, though pervasive human interference threatens to undermine the stability of these relationships. In consideration of recent trends in flooding as a product of plastic waste, cited in various academic works (Njeru, 2006; Windsor et al., 2019), we believe the Juan Diaz area will soon reach a point of no return, where the mounting severity of natural disasters and improperly regulated use of the land will render the surrounding land unfit for human cultivation or development.

2.1.3 - Types of pollution in the JDR

There are a variety of types of suspended and dissolved solid waste pollution in the Juan Diaz River; suspended in far greater quantities. Quantities of each respective form of pollution are summarized in Figure 1 pictured below.

	C144-Juan Díaz-E1	C144-Juan Díaz-E2	C144-Tapia-E1	C144-Tapia-E2
Sólidos totales (mg/L)	115.5	175.5	217	221
Sólidos suspendidos (mg/L)	2.75	6.2	20.47	13.63
Sólidos disueltos (mg/L)	112.75	169.3	196.52	207.37
NO3 (mg/L)	0.52	8.75	3.91	3.77
PO4 (mg/L)	0.09	2.81	9.95	10.22
Col. Fecales (UFC/100 ml)	90	110000	4900000	510000
Col. Total (UFC/100 ml)	520	320000	6500000	830000

Figure 2.3a. Adapted from 'Cuadro 109' in 'Diagnóstico de la Condición Ambiental de los Afluentes Superficiales de Panamá', this figure depicts various pollution metrics at 4 different sites (identified in the top row) along the Juan Diaz River. The metrics indicated in the far-left column translate to Total Solids, Suspended Solids, Dissolved Solids, Nitrate, Phosphate, Fecal Matter, and Total respectively. mg/L indicates milligrams per liter and UFC/100ml indicates UFC per 100 milliliters.

This table indicates that many solids within the Juan Diaz River are within their dissolved forms. There are a couple possible interpretations of this data. It could be assumed that the reason for the high proportion of dissolved solids is that most pollutants are readily soluble. Another possible conclusion is that this ratio indicates that the pollutants in the river have been there for long enough to break down into microscopic constituents, despite not having an inherent solubility.

2.1.4 - Main Sources of Pollution

While much of our research remains in the exploratory/researching phase, the current knowledge is that household waste such as non-biodegradable food packaging comprises the majority of solid waste pollution in the Juan Diaz watershed. The identification of the most prominent pollution sources remains one of our primary objectives; we intend to complete this with social outreach programs such as surveys and focus groups. The purpose of these efforts is to pursue some hypothesized issues contributing to pollution such as a lack of alternative

products, limited access to proper waste disposal sites, and a general lack of knowledge about 'green' habits.

2.2 - Marea Verde

Marea Verde Panama is a non-profit organization founded in 2017 by a group of environmental activists "to achieve a greener Panama" (Acosta, n.d.). The organization comprises approximately 20 environmental experts and works to improve the ecological health and communal knowledge about pollution in Panama.

2.2.1 - Mission

The mission statement our sponsor organization provides is as follows: "Committed to promote civic action and awareness on how to mitigate solid waste pollution in Panama's rivers and coasts" (Marea Verde, 2017). This mission is one that the organization has lived up to in organizing community outreach efforts to people living on the JDR watershed, and their success and milestones passed on previous environmental conservation projects.

2.2.2 - Prior Accomplishments

An ambitious first project led by the Marea Verde organization provided and continues to deliver astounding results in solid waste removal from another river in Panama, the Matias Hernandez River (MHR). Our sponsors installed a trash collection device modeled after the "Mr. Trashwheel" device developed in Baltimore, MD, in the MHR. It acts as a barrier to solid waste floating down the river towards the mangrove swamps and the country's coasts. They called this barrier the "B.o.B." which stands for Barrera o Basura or, when translated, Barrier of Garbage.

Since B.o.B.'s installation, they removed and prevented over 70 tons of garbage from being carried through the MHR to the coasts. This project also had a data collection component, of which they characterized the macro-plastics and other solid waste collected from the MHR. They used this information to determine the primary types of solid waste pollution entering the watershed, which they then used for future projects and educational outreach programs. (Marea Verde, n.d.) Building off of B.o.B., Marea Verde implemented another trash collection device, called "ReBoB", in the Tapia River. This device was made entirely out of recycled materials. The organization is working to incentivize the implementation of these "ReBoB" barriers to continue their work of not allowing solid waste to make it out of Panama's watersheds (Marea Verde, n.d.).

Marea Verde looks to stop trash from exiting the rivers because they strive to conserve the mangrove swamp ecosystems that bridge the gap between the rivers and the coasts of Panama. Due to the extreme neglect of these mangrove ecosystems, they are covered in trash washed out by the rivers and brought in by the ocean. To combat this, they work with other organizations with similar interests to rally volunteers to clean these areas and have removed over 400 tons of solid waste since their beginning (Marea Verde, n.d.).

To eliminate collected waste, Marea Verde designed a project to mix asphalt and collected plastic and pave roads with the mixture to use large amounts of recycled plastics safely. This proof-of-concept project showed that they could replace 1-3% of the asphalt aggregate with recycled plastic and effectively distribute approximately 6 tons of plastic in every 500 meters of road (Marea Verde, n.d.).

2.2.3 - Community Involvement

The Marea Verde Organization is not only centered around solid waste collection and environmental conservation methods, but it is also involved in community outreach programs to prevent the pollution of Panama's rivers. They have been instrumental in increasing environmental awareness through their "Green Classroom" program. They deploy environmental educators to schools near their recycling project sites to teach kids about recycling and conservation. The goal is for these students to share knowledge outside the classroom to create a cleaner future for themselves. Along with the "Green Classroom" educational initiative, Marea Verde collaborates with trash/waste collection and removal organizations to supply outposts for people in these watershed communities to drop off their trash if they do not have the means to otherwise (Marea Verde, n.d.).

Their outreach is not limited to person-to-person interactions and education; it has also been brought onto their organization's social media outlets. They have created the "BoB and Garzon Adventures", two animated characters that they have put into a comic-strip-themed format. The cartoon is available on their social networks and conveys serious environmental topics through an animated cartoon filter to reach a larger audience with a more variable age range (Marea Verde, n.d.).

2.3 - Data Collection

This project requires a few different types of data to be collected to understand all the different aspects of pollution in the Juan Diaz River (JDR). Geographical data helps to understand the JDR layout and the state of solid waste pollution accumulation at different

locations. Surveys completed by local communities provided insight on the social aspects surrounding the pollution crisis. The geographical information, combined with satellite images, and the survey results were used in our analysis.

2.3.1 - ArcGIS Software

Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS) is software developed by the Environmental Systems Research Institute (ESRI) to analyze, share, and interact with map data. It is capable of processing raster data and vector data. A raster refers to a grid matrix of pixels that contains information such as temperature or elevation and consists of satellite imagery, digital aerial photography, and scanned maps. They are helpful in the display and interpretation of geological data and associated environmental values. A vector refers to a point, polyline, or polygon that comprises spatial data for a given geographical location. They are used in a Geographic Information System such as ArcGIS to construct complex shapes and map features such as countries, hills, or bodies of water. With these functionalities, users can compile satellite, photographic, or scanned data into visually intuitive 3-dimensional maps for many purposes such as environmental studies, consumer use, and urban development. We intend to use this software to map out the Juan Diaz River while integrating essential data regarding pollution to devise environmental protection strategies.

2.3.2 - Satellite Imaging

We have access to satellite imaging through our connections with Marea Verde and the Panama University of Technology. We intend to gather data through these media to be processed by the ArcGIS software. This data will serve as the building blocks for complex maps. When the

images are taken, their coordinates are recorded and used to back-up survey responses from corresponding locations.

2.3.3 - Communal Surveys

Solid waste pollution has only one discrete source: humans. To develop a complete understanding of pollution dynamics within a community, it is necessary to monitor human activities, especially related to a citizen's role as a consumer. Consumer-directed products are undoubtedly a major source of available pollution material - products that have the potential to become pollutants - and can only be reliably tracked through human interactions. Because satellite data cannot track consumer-pollutant interactions, we have decided to devise surveys to distribute among the Juan Diaz River watershed residents to better understand pollution dynamics. From survey data, we hope to deduce the following:

1.) Does the respondent live in the Juan Diaz Watershed?
2.) What does their household garbage/recycling production look like? (Types of waste, reutilization of household objects, etc.)
3.) How is the garbage/solid waste their households produce collected or disposed of?
4.) What is the general knowledge and overall direct connections the inhabitants of the watershed have with the river?
5.) Is there an overall interest of the general public to participate in environmental studies or programs directed towards mitigating the issue of pollution in the JDR watershed?

6.) What relationships between the different communities can be seen when looking at pooled results of the various districts located along the river?

We would like to learn much more from the informal community residents, though we feel it is necessary to limit the contents of a survey to maximize participation and obtain reliable information.

2.4 - Socio-Environmental Impact

2.4.1 - Stakeholders

The work of the Marea Verde Organization is beneficial to a wide range of other organizations, groups, and people that utilize the JDR watershed, including the Panamanian government, the shipping industries and private businesses in Panama, and watershed communities living in the JDR's basins.

The Panamanian government has been promoting economic development in Panama, expanding its shipping industry, and introducing new districts to Panama City, which requires infrastructural development. Our project will benefit the Panamanian government because the data collected on the JDR will be used to further decrease the amount of waste polluted into the essential rivers of Panama. Hopefully the work completed on the Juan Diaz River can be replicated upon the more industrialized rivers in Panama, those rivers being the ones that supply water to the Panama Canal. When they are clogged with trash, it threatens the shipping industry, one of Panama's most economically stable and profitable industries (Linowes & Hupert, 2006).

Lastly, the Panamanians themselves will primarily benefit from our project's efforts. Identifying areas producing a large amount of river pollution and implementing communal

outreach to those areas to introduce the idea that solid waste needs to be managed appropriately and not dumped into the nearby river; will improve living conditions in these communities and allow for them to expand and grow and possibly become urbanized as the country develops more infrastructure.

2.4.2 - Improving Surrounding Ecosystems

Panama's natural Mangrove Forest ecosystems are under a severe amount of stress for several reasons, and one being the collection of solid waste within them. This pollution only impedes the growth of the forests, and without intervention, Panama will lose more of its Mangrove forests after previously losing 75% of these forests between 1980 and 1990 (Bulow & Ferdinand, 2013). Our project will give Marea Verde the information on the JDR that they need to prevent at least the waste coming from watershed communities. They will still have to worry about solid waste washing up from the ocean, but it will be drastically reduced once the JDR is "less polluted'. Hopefully, as the pollution rate decreases, the Mangrove forests will continue to be cleaned and stay cleaner, promoting their growth and expansion back into the robust ecosystems they once were. As there are mangroves located in the Juan Diaz River Estuary this research will hopefully in-directly benefit their native habitats.

Chapter 3: Methodology

The goal of this project was to assist Marea Verde in socially and topographically characterizing the Juan Diaz River watershed by identifying critical areas for intervention to help communities reduce their solid waste pollution levels. This project consisted of four primary objectives:

1.) Complete a visual analysis of the development of informal communities in the Juan Diaz River (JDR) area using satellite imaging and geographical mapping.
2.) Distinguished watershed boundaries in the community and, using the coordinates of the collected photo data, created a map of their locations to evaluate waste accumulation.
3.) Survey the communities on the watershed to assess their knowledge on the topic of waste disposal and associated habits using surveys.
4.) Analyze the resultant data for key trends and propose suggestions to combat the solid waste pollution crisis in Panama.

The resultant findings served as a prototype to be applied to other places where similar problems persisted.

3.1 - Objective 1: Juan Diaz Watershed Characterization

An aspect of the watershed we wanted to understand was how the area had changed over a certain period. To do this, we analyzed satellite images from different years and noted the quantity of new informal settlements that had been constructed. Determining to what extent the watershed had been urbanized was key to understanding the increased concerns the community had about garbage in the area. We requested the most recent satellite images taken in February

2021 from the Ministry of Environment in Panama while the older images from 2016 were taken from Earth Explorer. To complete this comparison, we utilized the tools in ArcMap in order to zoom in on the images to attain the most accurate representation of the changes that had taken place over the course of five years.

3.1.1 - Settlement Development

Satellite images taken throughout the course of a five-year period were used to evaluate the area of Juan Diaz to determine how the formation of settlements had changed over time. Using images from February 2021 from the Ministry of Environment to represent the most current state the community was in, and older images taken from the year of April 2016, we were able to perform a direct comparison of the two states the watershed had been in. These satellite photos can be seen in **Figure 3.1-1a** and **Figure 3.1-1b**. The older satellite images were retrieved from Earth Explorer at a lower resolution and were downloaded and uploaded into ArcMap as XML files. This was due to the images being in sentinel photo format. The satellite images that represented the current state of the community were requested from the Ministry of Environment in Panama from our sponsors and were uploaded into ArcMap as tiff files. Using different years to compare the area from a satellite view allowed us to gain a big picture idea of the urbanization that had been steadily occurring. Once the photos were uploaded into ArcMap using the Add Data button, the area of focus, which was the Juan Diaz watershed area, was zoomed in on using the Zoom feature on the Editor toolbar. Doing this allowed us to be detailed in our photo analysis of the area by comparing certain areas in both pictures for changes.

Figure 3.1-1a: Older satellite image taken from Earth Explorer.

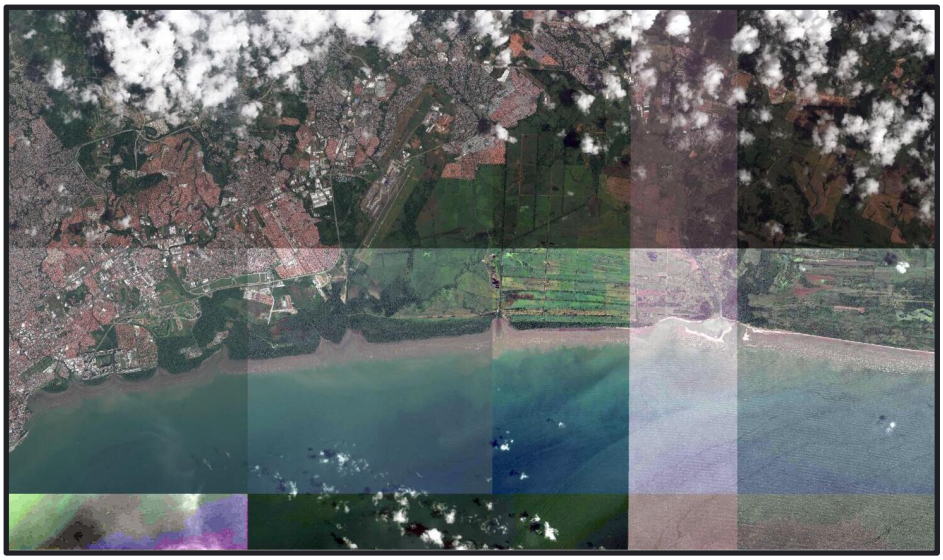

Figure 3.1-1b: Newer satellite image received from the Ministry of Environment in Panama.

3.2 - Objective 2: Solid Waste Characterization/Identification

Our team wanted more detailed information on what the pollution crisis looked like from a ground level perspective across the Juan Diaz watershed. Seeing the watershed from this point of view, we were able to better understand what certain areas needed and filled in gaps in our knowledge which could not be discerned from satellite or survey data. We concluded the best way to present this data was via map on Google Earth. Our sponsors collected and sent 47 photos at different locations within the watershed, along with corresponding latitude and longitude for each image (found in **Appendix C**). This allowed us to add each picture as a pin on the map in Google Earth. The pictures taken show us how much pollution has accumulated in an area, how the garbage is contained, and what the pollution is composed of. We made an analysis for each photo based on location and content shown, as well as rated each pin using a color-coded identification system. The system ranks each location as an area that does not need action, needs clean-up/action soon, or needs invention immediately. We created this map to be a tool for Marea Verde to use to identify areas to focus on for future clean up, surveying, and other work they see fit.

3.2.1 - Image Data Collection

Marea Verde member, Yasmina Rojas, photographed the watershed for us. The collection period took place between September 14th, 2021, and concluded September 26th, 2021 and included images of the JDR river/riverbed, nearby roads and highways, and neighborhoods. Images were shared with our team through Google Drive and received in the format seen in **Figure 3.2-2a**. In Google Earth, we first outlined the river and Juan Diaz watershed outline by using the *Draw Line* feature. We then added each photo individually into our Google Earth

project. To create profiles in Google Earth, the team opened our project folder, selected *New Feature* and, from the drop down, selected *Add Placemark*. A search bar appeared where we typed in the latitude and longitude in Cartesian Coordinate format and clicked *Enter*. The pin was created, and we selected the *Add to Project* and *Edit Place*. We then filled out the location information and added photos by selecting the camera icon and uploading the corresponding image from Google Drive.

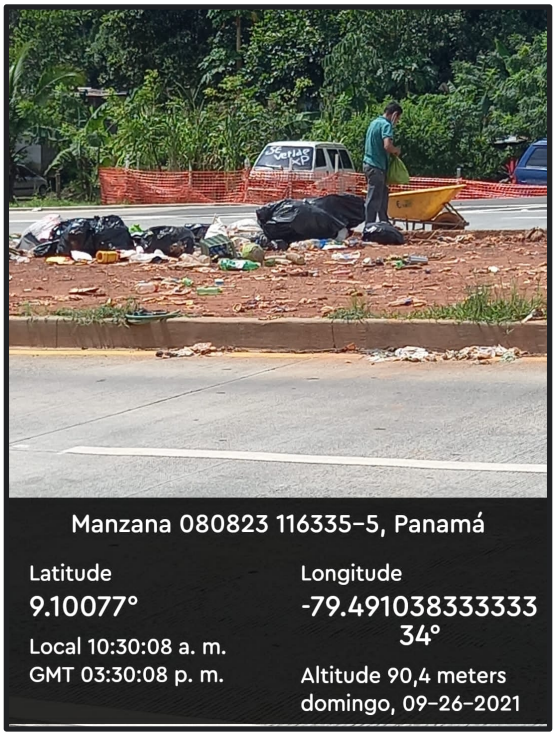

Figure 3.2-2a: Received as ground level image with Global Coordinates.

3.2.2 - Waste Accumulation Analysis

Each of the 47 photographs vary in pollution level, organization, and closeness to the Juan Diaz River. In order to evaluate the state of each location, we created a color-coding system to classify that particular area. There were 3 zones the images can be categorized as:

1. Green Zone
2. Yellow Zone

3. Red Zone

The Green Zone were areas that seem to have no solid waste pollution present or minimal amount of garbage that was well managed and far from the river (see **Figure 3.2-2b**). No action was needed in the green area. We determined Yellow Zones to be areas with a large amount of well contained trash 500+ meters from the river or a small amount of semi contained trash between 200-400m of the river (**see Figure 3.2-2c**). These locations did not pose an immediate threat to the river ecosystem but will require actions, such as physical clean up, soon. Red zones are high priority locations that actively have trash in and/or falling into the river (see **Figure 3.2-2d**). Coordinates labeled red were typically pinned within 100 to 200 meters of the river's edge and will need to be cleaned up as soon as possible and should also be checked up on at regular intervals to prevent future issues.

Figure 3.2-2b:(image cropped to show location) Green Zone with no trash

Figure 3.2-2c:(image cropped to show location) Yellow Zone with large amount of well contained trash (300 meters from JDR)

Figure 3.2-2d:(image cropped to show location) Red Zone large amount of loose litter entering JDR

Determining each image's zone color was dependent on the contents of the area. We first looked on a basic level of how much physical trash was in each area and deemed it small or large. Next, we compared how far from the river that point was and assigned it a color based on those two parameters. We then investigated greater detail how well the trash was contained, how

much was contained, and what types of trash (loose plastics, paper, large appliances, furniture, construction waste, etc.) can be distinguished from the image. We found this information important to consider because, if an image is labeled based on quantity and distance from the river, other factors, such as that pollution's ability to spread, are not being considered. Weather and terrain are two large factors that play a role in how fast and far pollution can travel. Not considering these factors could have led to the mislabeling of zones. For example, a zone considered Yellow could be very far from the river but have a large number of loose pieces of trash that are light and travel fast; the area should be categorized as a Red Zone. We summarized and added the analysis process for each image to its correlating profile (see **Figure 3.2-2e**). Once these final adjustments are made the profile is complete.

Figure 3.2-2e: This is an example of a completed image profile of a Yellow Zone.

To make each location to physically match its zone category in Google Earth, the locations pin color and icon are changed. Each zone color became the pin color, and icons for each color became as follows; green checkmark, yellow dot, and red "X". We changed the pin color by clicking a location's pin and selecting *Edit*. Next, we selected images designated color and under the *Placemark* tab by clicking on the paint bucket symbol and choosing yellow from the drop down. Similarly, under *Placemark*, all pin icons were displayed, and the correct corresponding icon was chosen. The process for creating placemarks in Google Earth Pro is the same process, except there are no pin icon options.

3.2.3 - Map Analysis

Our finished map holds a completed set of individual image profiles and watershed boundaries (see **Figure 3.2-2f**). The watershed and river outlines were added after all pins and analyses were completed. The watershed and river outline files were provided by our sponsors and added to Google Earth by selecting *Open* under the *File* drop down. Files were opened and automatically placed in the correct location. We achieved our goal of receiving more detailed insight that could not be gathered from surveys and satellite images, and we were able to pinpoint and categorize locations. With the color-coding system, we have created an organized map tool which identifies locations that physically need action to be cleaned up and regularly watched, which creates the opportunity for lasting pollution prevention and environmental improvement in the Juan Diaz River watershed.

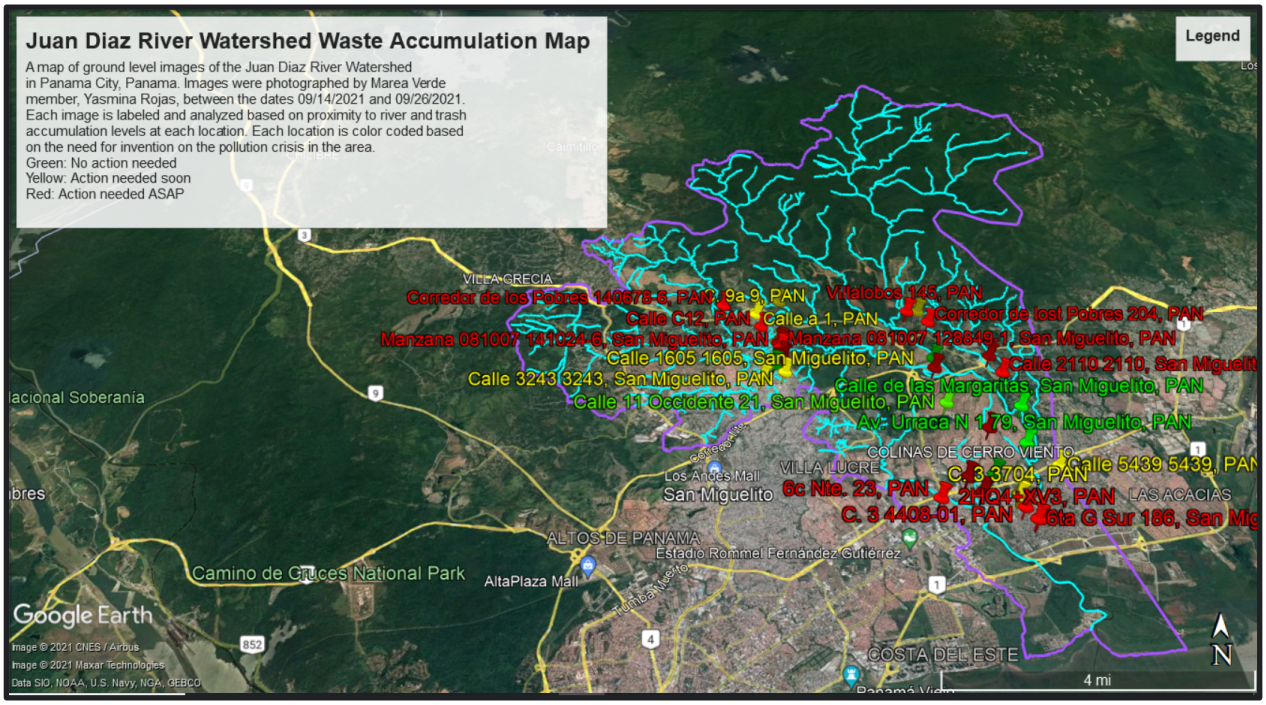

Figure 3.2-2f: The final draft of Ground Level Images map from aerial view (created on Google Earth Pro).

3.3 - Objective 3: Community Outreach

As the previous objectives were completed and we identified communities along the watershed contributing to the solid waste production polluting the JDR, we aimed to develop a better understanding of the community members' thoughts on waste disposal. We used a variety of different methods, as identified in this section, while considering the diversity of these communities and the varying perspectives based on the location. Since the team was not able to travel to Panama, all this data was collected by the Marea Verde organization. Marea Verde also distributed the surveys and then sent all information gathered to the WPI team.

3.3.1 - Data Collection/Surveying

From the data collected, the primary focus was on the Juan Diaz community, so the process of analyzing the results from the survey was. The survey was made up of 14 questions and was given in Spanish at mass community events facilitated by local governments, then the results were translated into English by the team. We hope our outreach impacted not only leaders in the community, but ordinary residents as well, since they are more likely to be contributing to the pollution of the river. To achieve this, we worked with Marea Verde's social research group to understand the scope of Panamanian life and the resources and infrastructure each community has access to. As the different communities are categorized using the ArcGIS software, we developed a detailed metric of the necessity of intervention and distributed surveys accordingly.

The survey targeted a wide variety of Panamanians, so the questions had the option to explain certain answers dependent on the individual's information. Topics such as Residential History, Waste Production Tendencies, Garbage/Recycling Collection Processes, General River Knowledge/Habits were kept in mind when creating the survey questions to better cater an intervention plan to individual districts and communities.

Note: These plans changed because the WPI group did not go to Panama, a representative from the Marea Verde Organization was asked to distribute surveys and interview questions and all results were sent to the WPI group for analysis.

3.3.2 - Local forms of Government/Leadership

We intend to target local forms of government or leadership as the primary source of information about the communities. Marea Verde representatives worked with them to facilitate the distribution of surveys to their community. We plan to develop more in-depth interview

questions based on the community leaders' perception of the issue and of their residents in addition to their view on the Panamanian Government. In these questions we will ask about their current status on getting resources from the government relating to mitigating solid waste pollution, and what they know about getting more. These questions will help establish a baseline for how often trash is collected, how much can be collected at once, and if it is a service provided to all communities by the government or a paid service. This baseline will assist later on when devising a plan to mitigate the solid waste pollution of these areas. This will be done in Spanish by a member of the WPI team that speaks Spanish, and he will hopefully be accompanied by someone from the sponsor organization that can assist where any language barrier presents itself.

Note: These plans changed because the WPI group did not go to Panama, a representative from the Marea Verde Organization was asked to distribute surveys and interview questions and all results were sent to the WPI group for analysis.

3.3.4 - Analyzing Communal Data

As we receive the results of the surveys, they will need to be organized and translated from Spanish to English before we can arrange the data they gathered. This will be done in part by the WPI team and reviewed by the Marea Verde organization to be sure that we are working with complete and accurate responses. Online language translation software in conjunction with previous knowledge of the team was used to translate the responses. These surveys were analyzed by grouping all surveys from the same communities together and then arranging them by similar communal aspects/interests. Finally, they will be grouped together by the rate at which pollution is deposited into the JDR. Research has shown that the average person in Panama City

produces approximately 1.22 kilograms of solid waste per day. In informal communities, the amount of waste collection will change the amount of waste accumulating and being polluted into the river. Communities with similar rates will have their survey responses regarding waste disposal beliefs/habits reviewed to generate a plan to reduce their pollution rates with a plan catered specifically to them and communities that fit each proposed category.

A statistical analysis of survey data will also be performed by the WPI project group to determine the statistical significance of the results. The number of people surveyed will determine whether the problems identified in the survey are by chance, or if they have a root cause that can be used to implement possible change. The data we will use in this statistical analysis will be obtained from population estimates for communal districts on the Juan Diaz River and the survey participant results will be provided by Marea Verde.

3.3.5 - Plans for Change

To develop plans for change, all of the data collected will be required. The river characteristics will help to determine which communities need reconciliation the fastest because of fast currents, high water levels, etc. Which will pull solid waste into the river at a faster rate. The ArcGIS image data will assist in determining those communities that are polluting the river with solid waste and that need to be surveyed first to begin working on a plan to reduce their pollution rate. The surveys will assist in creating catered plans based upon communal needs, they will help us to understand if education, infrastructure, or general resources are needed to help change waste disposal habits in specific communities.

3.4 - Objective 4: Methodology Summary

This project's overall objective was to understand the solid waste pollution situation about the Juan Diaz River and based on the collected data, create a proposal with different tactics and methods which would improve the efficiency of this process and its outcome(s). The desired outcome resulted in a solution that eliminated solid waste pollution in the Juan Diaz River and created a replicable process that can result in similar success for other rivers. Using ArcMaps to observe and understand the Juan Diaz River, the river's watershed, and the communities living in the river basin, as well as to pinpoint and categorize points at which garbage entered and formed deposits provided the necessary information to create a proposal for cleanup and control of waste near the river. Along with this, the community outreach aspect was equally as important because understanding the community's current actions, points of view, and overall knowledge surrounding the subject was crucial to catering a proposal to the communities that would be carried out successfully.

Chapter 4: Results and Analysis

This chapter contains the results and analysis of the different aspects of this project. Section 1 outlines the characterization of the watershed that was completed using the data sent to us by our sponsor organization. Some aspects of these sections have evolved based upon limitations of data collection which will be explained in the respective subsections and conclusion section. Section 2 presents the analysis of community data within the watershed, such as ground level image analysis, and pollution level comparisons. Section 3 holds the analysis of the communal survey data from Panamanians that live in the various 8 districts located within

the JDR watershed. The results in this chapter were all used to create our final deliverables given to our sponsor.

4.1 - Juan Diaz Watershed Characterization

This section will look at the satellite images and review some findings that we discovered while they were under analysis. Once the images were downloaded, they were uploaded into the software ArcMap and were ready for comparison. We were looking most closely at the general number of settlement rooftops in each respective image to determine if the percentage of residents had significantly changed.

4.1.1 - Settlement Development

Looking at the population in the watershed was an important aspect of our project for the purpose of understanding if this was a connection to the increased issue of garbage in the area. We completed a visual analysis of the two images, and we determined that the population had negligible changes. This was apparent by generally looking at the rooftops of the houses in the two different satellite images from the years of 2016 and 2021. It can be assumed that because the area of interest had approximately the same number of rooftops seen from both the images that there was a similar proportion of people settled in them at each respective time period. We were not able to quantitatively count each individual rooftop in the older, lower resolution satellite image because the settlements became very pixelated when they were zoomed in on. This made having an extremely detailed comparison between them unachievable, but still allowed for an estimate of the number of settlements in the community. It was important to note

that the population had sustained itself but the issue of waste in the watershed and amount of garbage accumulation in the area had increased.

4.2 - Solid Waste Analyzation

Reviewing the ground level images of solid waste compiled in the Google Earth map, there were few noticeable trends in solid waste accumulation. We categorized each of the ground level images based on how much trash is present, how well the trash is contained, what types of trash are present, and how close the location is to the river. Restating each color's baseline characteristics:

- Green: Distance is irrelevant. There was minimal to no trash present in the photograph.
- Yellow: This was dependent on trash level and distance to the river. (Meaning, it could be a small amount of mostly contained trash within 200-300 meters ranging to a large amount of uncontained trash 400-500+ meters from the river.)
- Red: All within 100-200 meters of the river's edge. These areas were covered in solid waste pollution and were noticeably causing harm to the environment.

This means our analysis process was based on our team's opinions and evaluations based on the parameters we created in the pin color coding system. We labeled each area based on how they fit within the 3 color categories. Next, we did a closer review, where we focused on the containment of trash and types of the pollution found. The reasoning behind this extra check was to consider how easily the waste could potentially travel (due to wind, weather, flooding, terrain, etc.). If this factor was significant enough, it could result in an area needing more or less attention which would result in the changing of its original anticipated color category. This entire

image analyzation process was recorded and displayed on the Google Earth Waste Accumulation Map.

4.2.1 - Communal Pollution Levels by Comparison

After analysis, the zone breakdown of the 47 original photos resulted in 6 Green Zones, 13 Yellow Zones, and 28 Red Zones. The 47 images taken were clustered in two main regions of the watershed, so they do not provide an accurate representation region (see **Figure 4.2a**). If we assumed these results were an accurate representation, the JDR watershed would be considered 12.77% Green, 27.66% Yellow, and 59.57% Red.

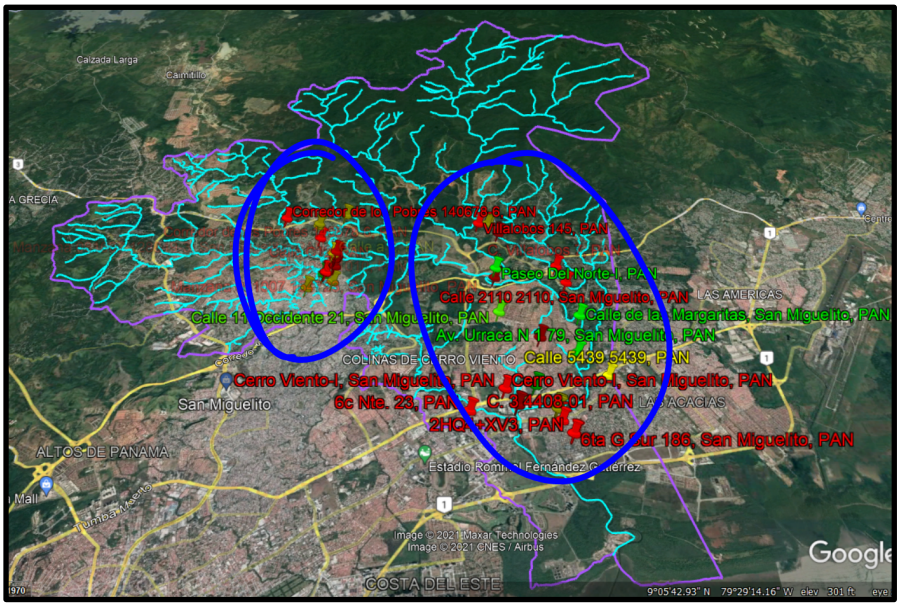

Figure 4.2a: Final draft of map with the two main data clusters circled in blue.

Since there was a limited data set, there was no way for the team to determine any trends in the pin location compared with their rating. We found a few clusters of yellow and red zones in some areas of the map, but that was due to the pictures being taken very close to each other and any analysis of the area to further determine trends was not able to be found in a picture alone.

Most of the analysis process, as stated previously, was subject to the team's personal review of the area. There was no way for the team to know the exact quantity in each area of how much trash was present, so the quantity of trash was estimated by the team through a subjective and comparative process (see **Figures 4.2b-4.2g**). We used this process to evaluate a range of data which would be used to color code the system accordingly.

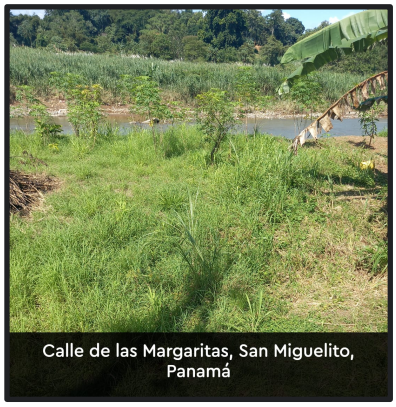

Figure 4.2b: Green zone with no trash present.

Figure 4.2c: Green zone with trash present that is well contained and fence in 200m from JDR.

Figure 4.2d: Yellow zone containing a very large amount of trash 400m from JDR's edge.

Figure 4.2e: Yellow zone with a small amount of well contained waste close (250m) to JDR.

Figure 4.2f: Red zone with small waste amount, but, due to being a busy road on the river side, this area needs regular attention.

Figure 4.2g: Red zone of river's edge covered in various types of trash that's sliding down the slope into the river.

4.2.2 - Community Image Analysis

Due to the lack of green areas, there was limited data to base conclusions on. All Green Zones were found on or near the river's edge, except one which was 800 meters from the river in an urban area. The images on the river's edge are composed of a small portion of the river and wildlife surrounding the river's edge which all seems to be uncontaminated by any pollution. The

one outlying photo is of a street with buildings and a grassy road median. There is no trash present except for some small paper trash on the median. Due to the miniscule amount, farness from the river, and how well kept the rest of the area is, we concluded this area to be a green zone. If the area had been closer to the river (400 meters or closer), the rating of this area could have been different. As a team, we reviewed the green areas and determined that due to the state of all images in this category no action would be needed in these areas. These areas had no evidence of any sort of waste harming the environment and/or was far enough away where the waste would not reach the river.

Yellow zones made up just more than a quarter of the pin results on the final map. We reviewed these images as a whole and found all yellow category locations were street sides in suburban areas all ranging in distance from the river. In regard to waste accumulation, the photos in this category had the largest variety. We found there was no one reason to explain this variety. However, in its simplest form, our definition of a yellow zone was a sort of pollution neutral ground where there was no harm being caused to the environment to call for immediate action, and the waste in this area we determined to be unlikely to travel/travel far enough to affect the river to constitute action. The zones, therefore, were classified to be in no imperative rush to be cleaned up but should be physically cleaned soon. After reviewing these images, the team also came to the conclusions that some of these areas may need a more organized waste collection system. We found there were many areas with both large and small informal community trash piles (see **Figure 4.2h**). These unstructured trash piles are the cause of most yellow and red zones.

Figure 4.2h: Red zone caused by an informal trash pile near the river's edge.

Red zones resulted in the largest quantity of areas and were prevalent across the watershed. Of these pictures, 13 of the 28 occurred on the JDR/river's edge, and the 15 images occurred within 200 meters of the river's edge. Locations found on or around the river were determined to be cleaned up as soon as possible since these areas are causing the most risk to the environment (clogging, cluttering, physical damage, etc.). The areas within the 200 meters were causing similar damage to the watershed but also carried the additional impact of having pollution that could spread easily to surrounding areas. For these reasons, the team determined red zone locations should be cleaned up immediately and on a regular schedule to avoid further environment complications.

4.3 - Community Outreach Survey Analysis

This section will analyze the survey distributed by our sponsor organization, Marea Verde, within the JDR Watershed in Panama to residents coming together for mass communal events. These events being vaccination sites for COVID-19 vaccines, communal training, or any other mass events local authorities would help facilitate the distribution of these surveys. The

survey has been ongoing from mid-September throughout October 2021, and the most recent results have provided 179 complete surveys from residents of the 8 different districts along the watershed **(see figure 4.3)**. The survey was designed conjunctively by Marea Verde,

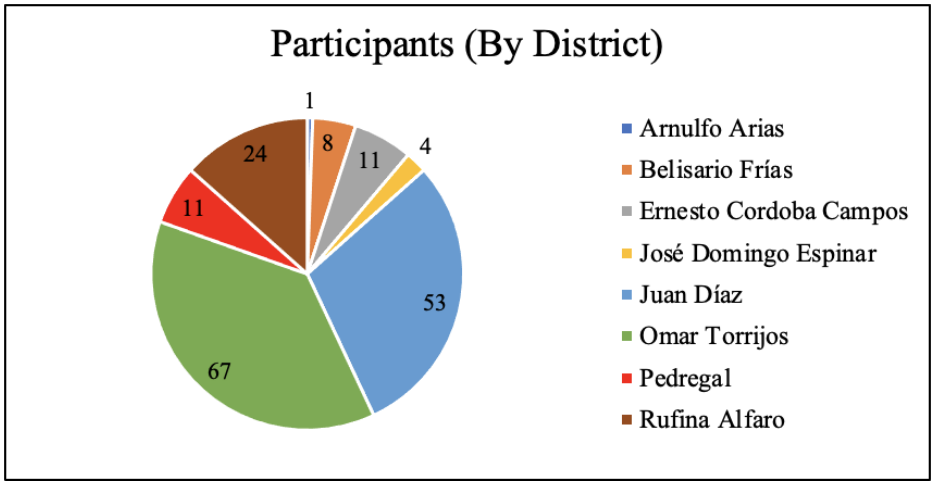

Figure 4.3a: This figure is a pie chart representing which district on the JDR Watershed each of the survey participants' households are located in.

and the University of Miami with some questions designed to aid in data comparison added by the WPI Team. The survey mainly focused on topics such as: Residential History, Waste Production Tendencies, Garbage Recycling/Collection Processes, and General River Knowledge/Habits. A copy of these survey questions is available in **Appendix D**. The following subsections will present the analysis of the resulting survey responses.

4.3.1 - Residential History

Understanding the residential history of the survey participants allows us to understand the reliability of the survey from a few different angles. First and foremost being whether they

could answer questions with historical accuracy. For example, Question 11 in the survey asks for a comparison of the river's condition of the river the respondent is identifying over the last five years. If the residents responding to that question have not lived in the JDR watershed for at least five years, then their answer is not based on first-hand knowledge and could be less reliable then someone who has. As shown, in **figure 4.3b,** 74% of the respondents have lived in the district with an average residency of 14.2 years. This average is one that adds to the reliability of these results because most residents will have personal historical knowledge about their surroundings. It was also very useful to survey residents that have lived in the watershed longer because they were the respondents that tended to know of a river or stream that was located within 500 meters of their household.

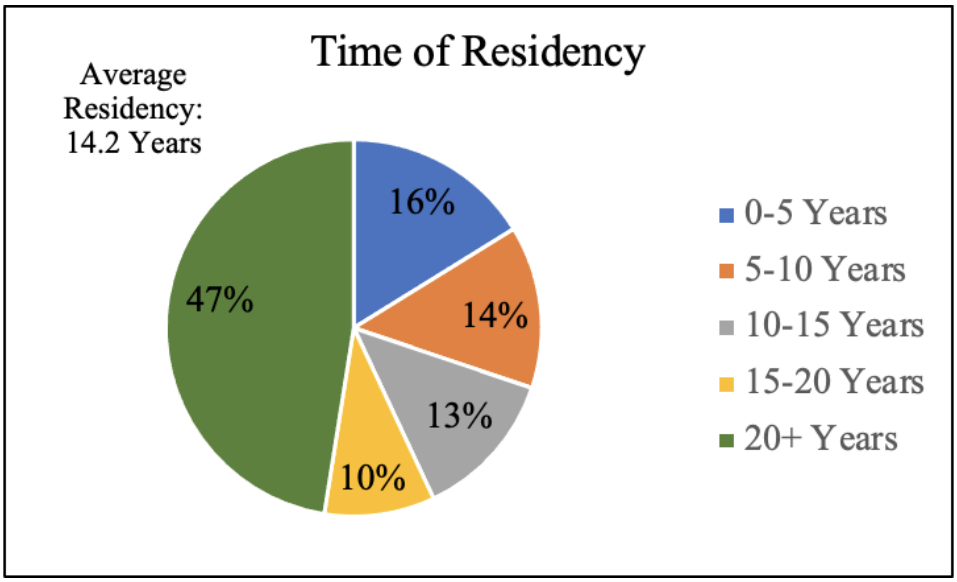

Figure 4.3b: This figure is a pie chart that represents the length of residency of each survey respondent in their respective districts.

Location was also one of the subtopics of the residential history questions because in this experiment we are trying to limit the results to people that live within the Juan Diaz Watershed.

Along with question 1, asking about the respondents' respective districts, the sector was also asked to further pinpoint responses to people that have some form of a connection to the river within 500 meters. This answer correlated with the number of respondents that said they knew of a river that was close to their homes and whether it is the Juan Diaz River, as shown in **figure 4.3c**. This info can be checked on the satellite maps since river connections within the sectors are visible from the overhead view.

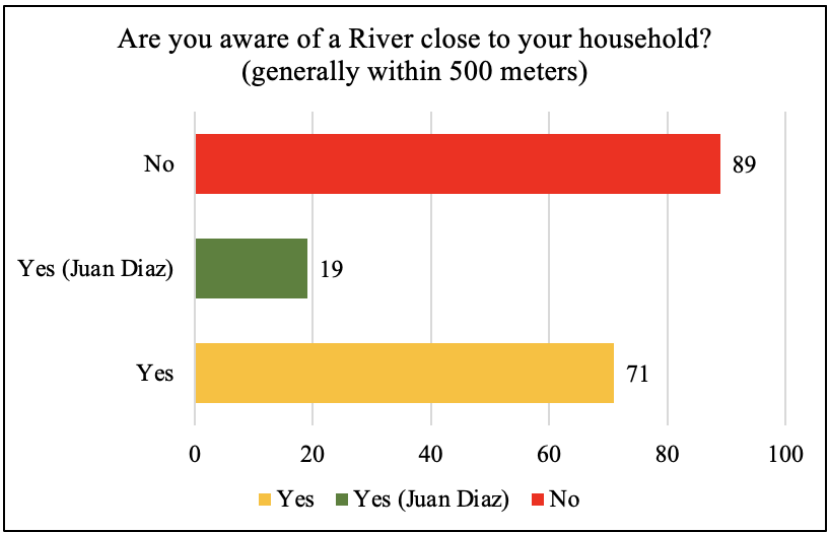

Figure 4.3c: This figure is a bar graph representing the amount of people that know of a river close to their household. In red are the responses of people who did not know of a river, yellow are those that knew of a river but not the name or it was not the JDR, and green are the respondents that could confirm a connection to the JDR close to their household.

4.3.2 - Waste Production Tendencies

The questions designed to understand what kinds of waste were being generated in the JDR watershed households confirmed a lot of the expectations the team and Marea Verde had for these communities. From the data the consensus is that they are consuming and producing solid

waste that comes from commercially or industrially produced methods such as plastic packaging, as shown in **figure 4.3d**, and other common household trash you would expect from a developing district outside of a larger city.

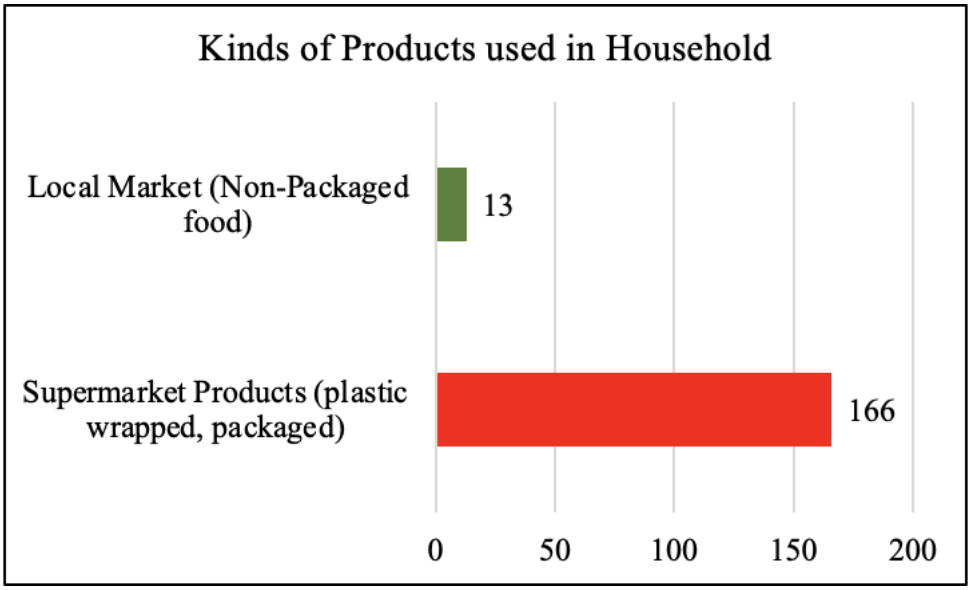

Figure 4.3d: This figure is a bar graph that represents the answers to survey question 3, as shown in Appendix D, in red are the responses that indicated they generated solid waste in the form of product packaging, and in green are the responses indicated their consumption was from local markets with lightly packaged foods (non-plastic or commercially packaged items).

The next question falling within the category of waste production, was intended to understand the general population's habits on reusing items that have disposable counterparts.

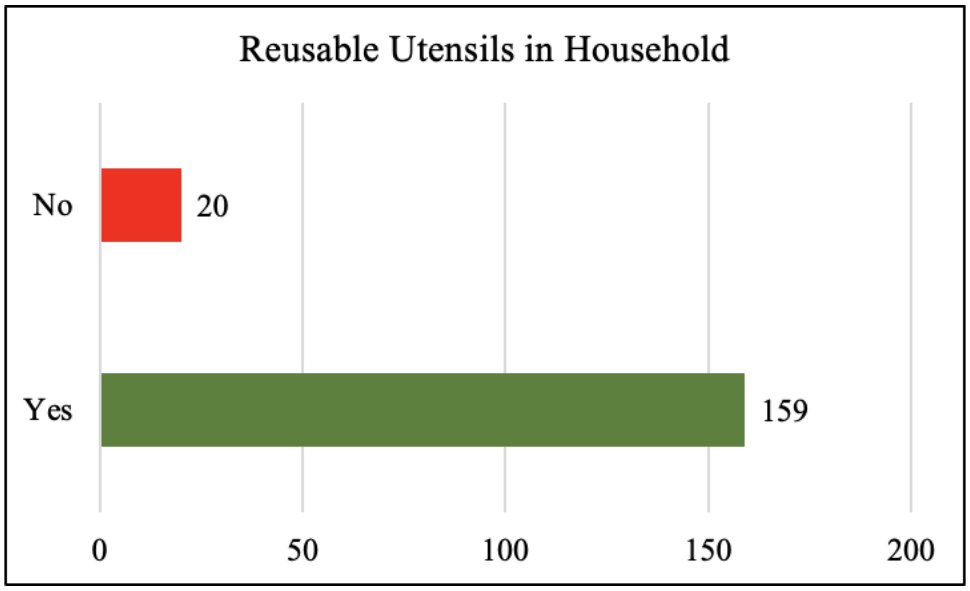

Figure 4.3e: This is a bar graph representing the number of households that use normal reusable utensils such as silverware, plates, cups, etc.

Looking at **figure 4.3e**, it is evident that most households, 88 percent of them, use mostly reusable or recyclable utensils that otherwise could be adding to the environmental pollution in the watershed. The results in this section begin to point towards the conclusions of a waste collection issue in the watershed, which will be referenced in the following chapter.

4.3.3 - Garbage/Recycling Collection Processes

The results in this section allowed the group to understand the ways that the respondents' garbage is supposed to get collected or disposed of and conceived the idea that there may be some issues with the current systems in place. According to the survey results, 72% of the

households coming from the various districts are supposedly leaving their garbage out for street pickup, as seen in **figure 4.3f**. Even if there is no street pick up there is still the option of

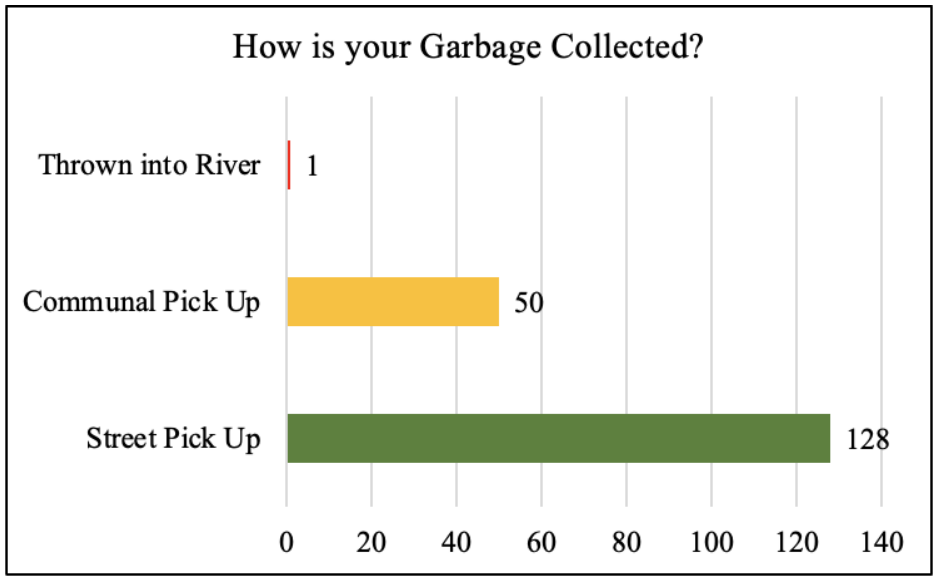

Figure 4.3f: This is a bar graph representing how the garbage is disposed of or collected from the residents of the 8 districts that the respondents lived in.

bringing the waste to a communal disposal area. When comparing that data with the data represented in **figure 4.3g**, we see that about ⅔ of the survey respondents have issues with garbage collection in their respective district. This data in conjunction with the data in the previous subsection leads us to think the infrastructure is not capable of keeping up with the solid waste production in some of the districts located in the Juan Diaz Watershed, a topic that will be further discussed in the next chapter. The final data set related to this topic was asking the

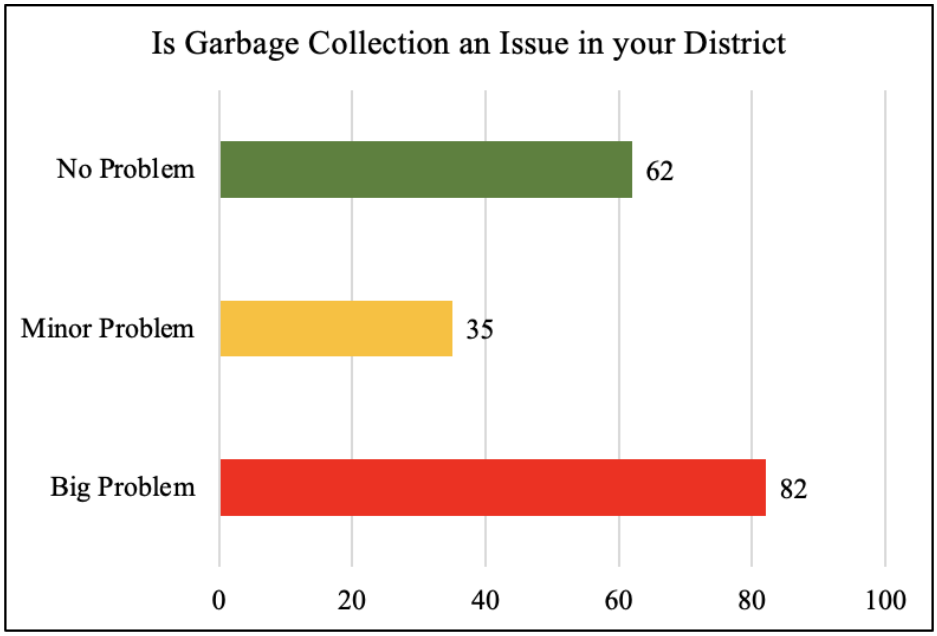

Figure 4.3g: This is a bar graph representing the data for question 6 in the survey presented in Appendix D. In green, are the responses indicating they have no issue with their trash and recycling collection. In yellow, are those that indicated a minor problem with their solid waste collection. The responses represented by the red, and largest, bar is those that have a big problem with their trash collection.

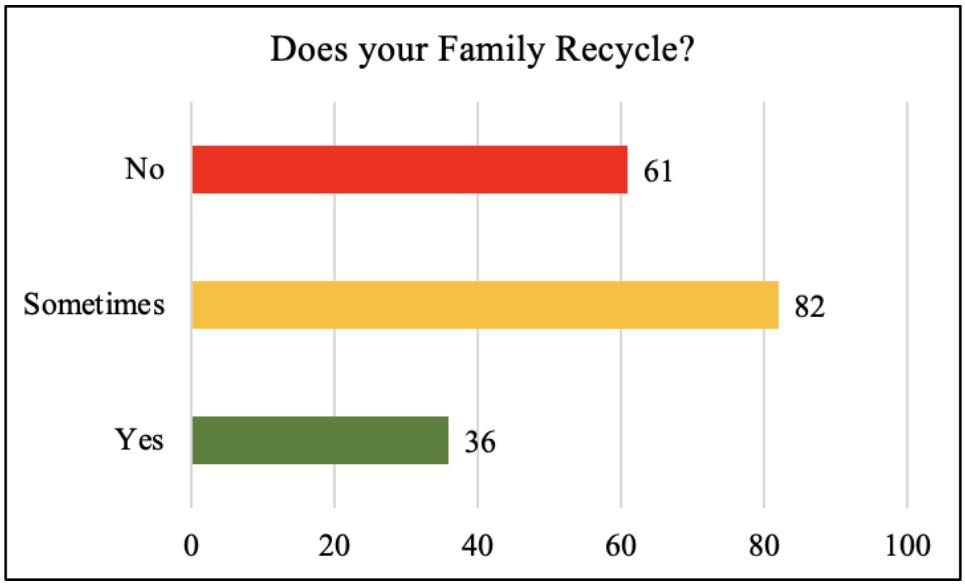

Figure 4.3h: This is a bar graph of the survey responses to question 7 in the survey presented in Appendix D. The red represents the results of the respondents who do not recycle in their household. The yellow bar represents the households of the watershed that recycle sometimes, and the green represents those that recycle regularly.

question to determine some general habits of the people inhabiting the watershed and we learned that at least a third of the total people surveyed don't recycle at all. A much smaller number then the amount of people that produce recyclable waste, which was seen in the responses in the previous questions.

4.3.4 - General River Knowledge/Habits

This section contains the data reflecting the perception of the river collected from the survey responses. From **figure 4.3i**, it is seen that about 60% of the respondents believed the river's, whichever they identified near their household, condition has worsened over the last five

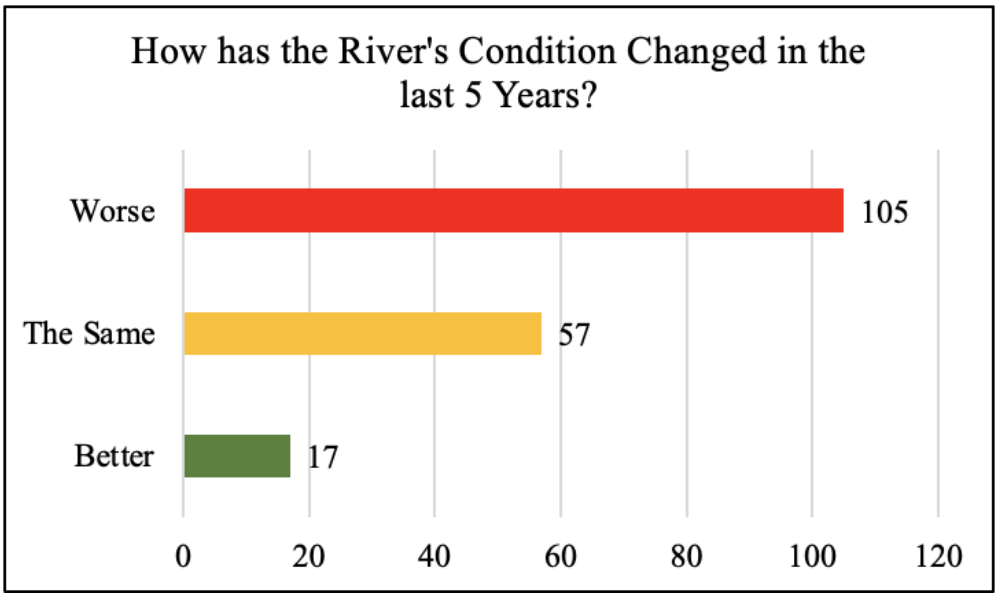

Figure 4.3i: This is a bar graph of the survey responses to question 11 of the survey seen in Appendix D, asking about the river's condition and how it has changed over the last 5 years. The red bar represents those who responded that the river's condition has gotten worse in the last five years. The yellow bar represents those who haven't seen a difference in the time frame, and the green represents those who saw no change in the past five years.

years. This data is of extreme interest to us because most of these same respondents have, or believe they have, the means of disposing of their trash in such a way that it will be properly handled by waste collection services. Their rivers are continuing to become more and more polluted.

The residents of the watershed understand that pollution to the river is detrimental to their own or their family's health, but they also understand the same principles for the surrounding ecosystems and oceans, shown in **figures 4.3j-4.3k**. All of these data sets are allowing for a

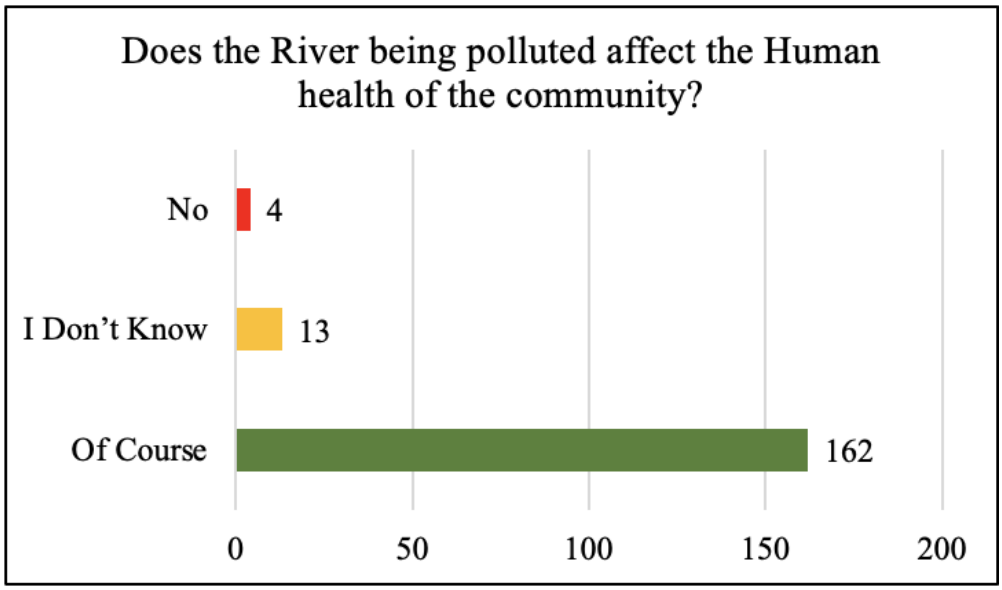

Figure 4.3j: This is a bar graph presenting the responses from question 12, and the question asked was whether the river being polluted would affect human health in their respective communities. The red bar represents the people who responded no, yellow represents the people who didn't know the answer, and the green represents the people who answered yes.

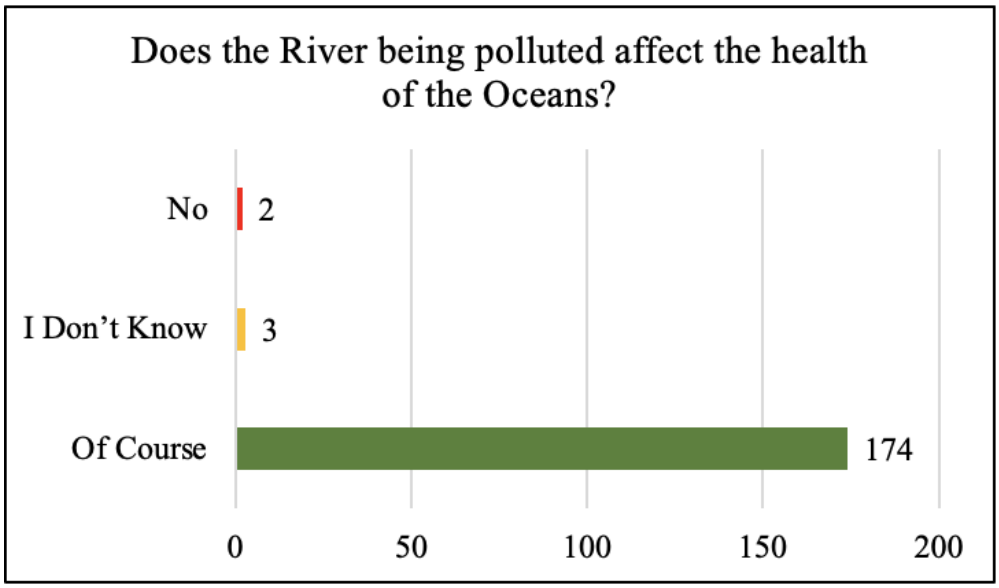

Figure 4.3k: This is a bar graph presenting the responses from question 13, and the question asked was whether the river being polluted would affect the health of the oceans. The red bar represents the people who responded no, yellow represents the people who didn't know the answer, and the green represents the people who answered yes.

centralized problem to be identified in the trash collection that occurs, or seemingly does not occur, in some of these districts. This idea is only further confirmed by the data in **figure 4.3l**, showing that 93% of the survey respondents don't have any direct connections with the rivers nearest to them. This idea will be further discussed in the following chapter.

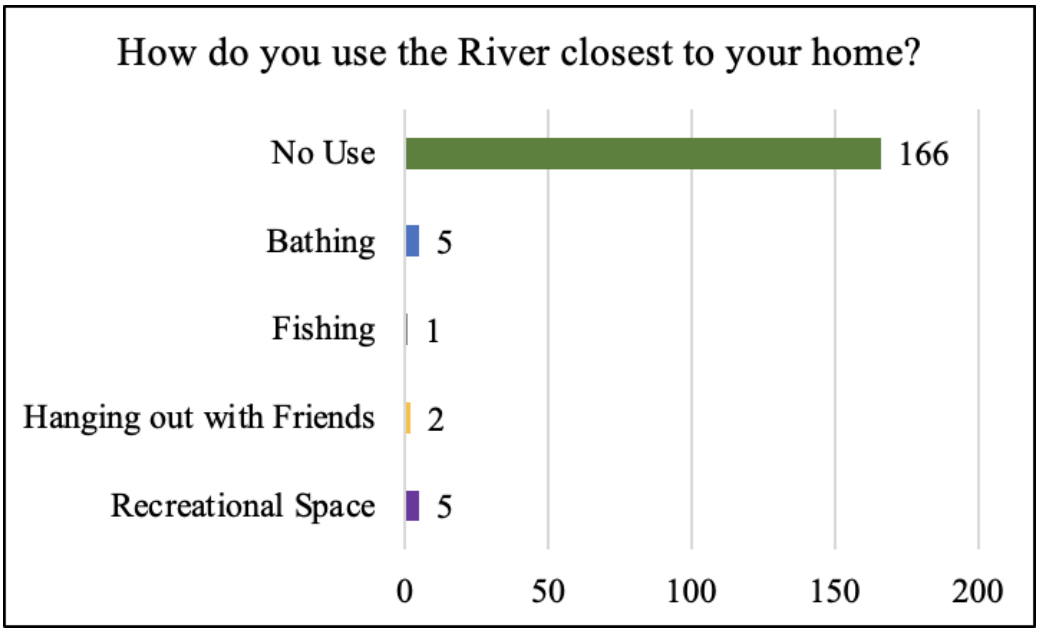

Figure 4.3l: This is a bar graph presenting the responses from question 10, the question being what are the uses you use the river near your home for. The green bar represents no use, the blue bar represents bathing, the gray bar represents fishing, the yellow bar represents hanging out with friends, and the purple bar represents the people who use the river as a recreation space.

4.3.5 - Environmental Study/Outreach Interest

In this section the interests for a communal outreach program and future studies related to pollution in the watershed was gauged. This information would be useful to Marea Verde when determining when and where to put on their next outreach program. More feedback in this response may be helpful to understand the kind of outreach these people are looking for. As seen in **figure 4.3m**, a communal outreach program would help the pollution issues facing the districts, so catering it to be most effective would be the best option. It appears these

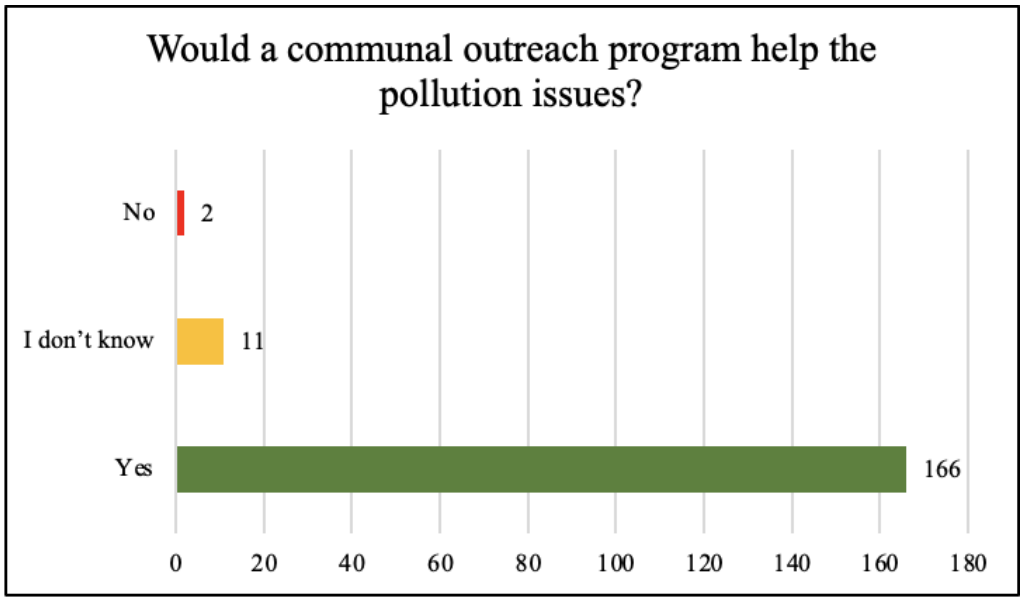

Figure 4.3m: This is a bar graph presenting the responses from question 8, asking if a communal outreach program would assist the watershed communities with their pollution issues. The red bar represents the people who responded no, yellow represents the people who didn't know the answer, and the green represents the people who answered yes.

results also point towards the discussion in the next chapter about an outside organization supplementing or adding on to the garbage collection infrastructure in the watershed. Because according to **figure 4.3m**, the participants think an outreach program would be beneficial, but the ambition or need to participate doesn't seem to be there as well, as seen in **figure 4.3n**.

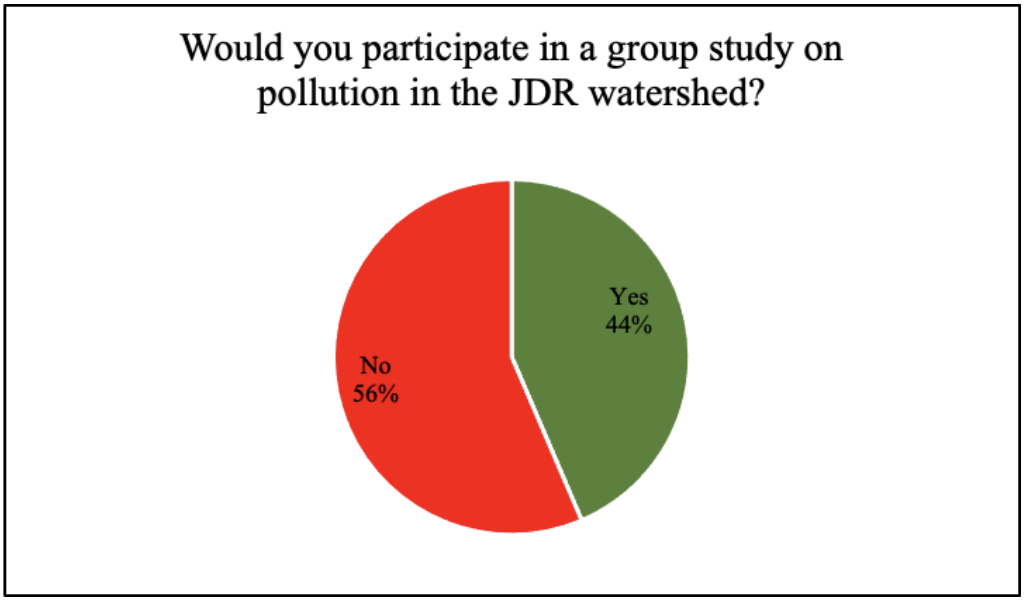

Figure 4.3n: This is a pie chart presenting the responses from question 14, asking if the respondent would participate in a group study on pollution in the Juan Diaz Watershed. The red section represents the people who responded no, and the green represents the people who answered yes.

Chapter 5: Conclusions and Future Directions

This chapter begins to draw conclusions from the analyzed data to understand how it connects and shows direct connections that point towards a larger cause of the pollution problem in the Juan Diaz Watershed in Panama. The first section will outline the satellite data and what conclusions were able to be drawn solely from it. Next, the solid waste identification section will focus on the google earth project and the conclusions that were drawn from the ground-level communal photos from 47 various locations in the watershed. Then the community outreach section will focus on the assumptions that came from the survey, and what conclusions could be

drawn when identifying the relationships between the different questions. The final section will give an overview of the previous three sections and show how the three different forms of data analysis can be used together to determine the next best course of action for Marea Verde and the JDR watershed. This section will also discuss some of the limitations the WPI Team experienced over the course of this project.

5.1 - Juan Diaz River Watershed

This section focuses on the analysis of the satellite images retrieved from the Ministry of Environment in Panama and Earth Explorer. An analysis of the population changes over the last five years observed from the images will also be included in this section. Briefly mentioned will be some of the limitations of these images due to specific circumstances that impacted our final analysis and conclusions.

5.1.1 - ArcGIS Conclusions

There are a few conclusions that resulted from the satellite images used during this project; the first is related to the population in the watershed. We could determine that there had not been any significant changes to the overall population in the area over the past 5-10 years based on community/settlement development. This was known due to the comparison of the older and newer satellite images. As a result of the poor-quality satellite image of very low resolution for the old image, very broad conclusions about the population were made because an in-depth analysis was not feasible. It was challenging to determine any minimal to moderate changes to the watershed, but any significant or very apparent changes to the number of settlements in the area were noted.

The second conclusion we were able to make asserted that garbage pollution in the river and around the watershed will persist. This was because we determined that the population over the course of a five-year period had minimally changed, but the issue of waste in the area had increased. When we paired the satellite images with the survey results and ground images, it was clear to see that as the population sustained itself, the quality of the environment around these urbanized areas worsened.

5.2 - Solid Waste Identification

The Solid Waste Accumulation Map created in Google Earth was created with the goal of creating an organized map system labeled with pictures and analysis (of each image) to gain a more in depth understanding as well as an evaluation of the watershed. This map was also designed to be a tool our sponsors could use for information or as a guide to find potential focus areas within the watershed. We were able to understand the area, create conclusions, and determine potential future steps that could be taken to improve and protect the Juan Diaz watershed environment.

5.2.1 - Google Earth Project Conclusions

Based on the analyses made in the different areas, we used our pin color coding organization system to generalize our conclusions on what each section needs. Areas labeled Green, as stated before, were in a stable state where no action was needed. These regions did not have any visible trash causing/that could cause harm or waste collection system issues that were prevalent in photos. Therefore, it would be best to leave these areas alone where no work would be needed and focus efforts on yellow and red zones.

We labeled yellow zones as a sort of neutral or grey area when it comes to needing attention. The photos in these locations showed us varying amounts of pollution; however, the solid waste in these areas were not yet directly harming the Juan Diaz River restoration process. It was determined by the team that there would be time before the pollution of yellow zones becomes harmful. We concluded evaluating these areas again in a few months to have a more accurate understanding of the area, see any improvements, develop a regular clean-up plan, and research the waste collection system of that location. We found that not knowing how trash was collected in each area was a limitation in our analyses of the watershed but seemed to be a common concept that varied from location to location, in quality, and in resources.

The understanding, concepts, and conclusions of red zones is very similar to that of Yellow, except more extreme. Red zones need attention immediately. We found the harm to the environment these locations are causing needs to be rectified as soon as possible. Trash was eroding into the river spreading down river, worsening the clogging issues, and generally aggressively littering the watershed. The team determined red pins need physical clean up immediately and on a regular basis. Red zone areas seem to get a lot of foot and car traffic or seem to be people's backyards. Due to the constant action, they receive, regular clean up (every 2-3 months) is a necessity. The implementation of waste disposal did not seem prominent in most of these photos and should be investigated. Few pictures did include a dumpster; however, evidence from the images indicated these dumpsters are not adequate for reasons of it not being emptied regularly or soon enough to where it has become a danger to the environment.

Overall, the waste collection system in the Juan Diaz River watershed needs to be reevaluated. The physical cleanup is a temporary short-term solution to a larger problem. A

waste collection system that is easily accessible and regularly cleaned throughout the watershed is needed to have a successful restoration of the Juan Diaz River.

5.3 - Community Outreach Survey

This section focuses on the survey distributed by Marea Verde and analyzed by the WPI Team. It will outline the conclusions drawn from the survey results. As well as, what the relationships between the responses to different questions point towards the current issue and the potential next steps in the watershed. It will also go into some of the changes the WPI Team believes would be beneficial to future surveys conducted in similar areas inside or outside of Panama.

5.3.1 - Survey Conclusions

The main conclusion that can be drawn from the survey responses is that there is a pollution issue, but it is not due to incorrect habits by the residents of the Juan Diaz Watershed. According to the surveys, collected directly from Panamanians along the Juan Diaz River, most of them believe they have means of garbage disposal. In the same survey, many of these respondents who answered that they either have street pick-up or a centralized communal drop-off location answered that they have garbage collection issues in their respective districts. Those two points obviously contradict each other, leading us to believe that in some places these infrastructural systems are in place and as the informal communities in the watershed continue to spread and develop the people who moved in followed their neighborhood counterparts, in

disposing garbage, until the population eventually exhausts the garbage collection capabilities of the district.

Those two questions in the survey were not the only ones that pointed towards this conclusion. When asked if the residents use the nearby rivers, there was an overwhelming majority of responses that confirmed that they have no use or direct relationship with the river. Therefore, these watershed inhabitants are watching the condition of the river get continuously worse, and are recycling and using reusable materials, when possible, but they don't use it. Similar ideas are drawn from the pollution knowledge question as 90 or more percent of respondents answered that the pollution in the river is unhealthy for human health as well as ocean health. The Panamanians of this watershed understand pollution and that it is an issue, as well as the fact that their garbage needs to be disposed of but have no option to do so properly.

5.3.2 - Improving the Survey

The WPI Team was of aid in customizing minor portions of the distributed survey, but it was mostly created in part by Marea Verde and their colleague at the University of Miami. After analyzing the results from this survey there are some changes the team would make in order to get more specific answers to understand more about the causation of the pollution in the watershed. Those changes being:

- Survey response location pinpointing
- Survey distribution
- Government provision of garbage collection infrastructure

Knowing the survey response location would be extremely beneficial when trying to utilize this information with other forms of data to relate them together and build a better understanding of the pollution problem in the JDR. It would have allowed for a lot more implementation into both ArcGIS and Google earth as mentioned in previous sections of the chapter because the information is dependent on geolocation and georeferencing the data onto the various maps.

Changing the mode of survey distribution would also be extremely beneficial because it would give us a less broad area to focus in. Which would make it much easier to draw conclusions and potentially take immediate action if there are sites that need it and an organization has the means of doing so. Surveying an entire watershed with a very limited number of surveys is not conducive to solving the issue in the entire area. If the survey results were more concentrated when it came to location, then one area could be rectified at a time. In that process, the methods used in each previous location could be applied and adapted making the situation much easier from a facilitative standpoint. It will be very difficult for Marea Verde to change much in the entire watershed without creating small focal areas and expanding off of them.

Understanding what the government or district officials have told each respondent about means to take for garbage disposal would be very beneficial to the team as well because we would know what the potential of each district's solid waste collection infrastructure was. This aspect being added to the survey would confirm our suspicions of the fact that the district is developing, and the Panamanian government has not made sure that the infrastructure was able to handle it. The people cannot be blamed for the influx of pollution because according to the survey they are consuming commercially packaged products, and especially if these are the only,

or most cost effective, products available, getting rid of the waste consuming them is not the inhabitants of the watershed's fault. Which may also connect back to the majority of people not wanting to participate in environmental studies relating to pollution in the future because they may not want to have to help out in creating a basic provision, they should already be receiving for being a Panamanian citizen.

5.4 - Overall

This section includes the overall conclusions that the WPI team made when connecting all forms of data relating to pollution in the watershed. Those being the ArcGIS satellite data, the google earth project, and the community outreach survey. It will also include some of the limitations that the group faced in those various aspects of data analysis and conclusion drawing. The final subsection will also contain the parts of the project that were unable to be completed because of the respective limitations.

5.4.1 - Overall Conclusions

From all of the data analyzed, it has become obvious that the root of the pollution issue in the Jan Diaz River Watershed did not start within the last 5 to 10 years. The surveys showed a consensus from all survey respondents that the condition of the river is not getting better, it is either staying the same or getting worse. A statement further supported by the ground-level communal photos of trash not being collected and being exposed and uncontained in residential neighborhoods.

Therefore, our conclusion based on all data points we were able to consider with all the limitations faced, we believe that this problem has surpassed all volunteer or pollution awareness organization efforts. The solution will have to be conducted by the Panamanian government with funding and appropriate resources that will be able to remove all of the piled-up garbage and enough to support the ever-growing populations along the watershed. The residents of the watershed see and understand the issue they are being faced with, but do not have the basic provisions a government should be providing to rectify it. The people who have the means to recycle, will recycle, the people that have the means to clean up the environment will do just that. No one wants the place they live to be overrun by garbage, so obviously this is a problem that has been ignored by both the local governments and Panamanian government for too long, and if they are concerned with the current state of the environment, they will have to make large contributions to these efforts.

5.4.2 - Limitations

There were many limitations to this project, the biggest and most adverse being the inability to travel from Worcester, MA to Panama due to COVID-19 related restrictions. Which was not only a limitation for the WPI Team to perform the necessary tasks to complete this project, but also for our sponsor organization, Marea Verde. The climate in Panama, regarding COVID-19, was deemed unsafe for travel which also drastically extended the timeline of getting the necessary permits to perform their communal surveys. The WPI team did not receive the batch of survey results used in this report until October 6, 2021; and the report was completed on October 12, 2021. In this amount of time, the team was unable to perform a deep analysis of the invaluable survey data provided from actual residents from our project site. This made

connecting data and drawing conclusions extremely difficult because the methods of the project had to be very fluid to support the ever-changing amount of data we were hoping to receive.

Another limitation experienced in the completion of this project was the lack of a clear goal. The team was unsure of what the final goal of the project was until week 5, the first week of survey distribution, and that made planning deliverables very difficult so most all work had to be completed once we knew what data was available to work with. Many of our original goals were unable to be completed due to either data or time restraints. One being, a statistical analysis, which would have required completing a population estimate of the current Juan Diaz Watershed. This was the original plan; however, the Ministry of the Environment in Panama did not provide us with the necessary satellite data to do so until week 5 as well. This placed a hard learning curve in ArcGIS/ArcMaps on the WPI Team. One that was unable to be overcome due to different conflicts in scheduling with the sponsor's colleague and the inability to collaborate to understand the different georeferencing struggles we were having with the mapping software.

5.4.3 - Recommendations/Future Directions

Overall, the project completed does yield some valuable data for Marea Verde, but it is incomplete. The survey is still being distributed and the results will need to be added and compiled again once there is more. Some future directions we suggest for Marea Verde would be completing a statistical analysis of the survey based upon the district once the survey collection is finished. A population estimate would be needed and from the resolution of the satellite imagery obtained from the Ministry of Environment that should be possible by counting rooftops like we planned to. That way the data can be statistically significant when presenting this data to

whichever organization that will need a proposal to rectify some of the issues of pollution in the Juan Diaz Watershed.

In addition, we advise that Marea Verde focus on smaller subunits of the watershed and work out from there because it won't be feasible to make change to the whole watershed at once. There is not enough infrastructure or control in these informal settlement portions of the districts to support the rapid influx of trash collection regulation processes.

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Appendices

Appendix A: Original Copies of Law Documents

Law 41 1998: Gaceta Oficial Digital

Ley Basura Cero: Gaceta Oficial Digital

Law that regulates the reduction and replacement of single use plastics:
QUE REGULA LA REDUCCION Y EL REEMPLAZO PROGRESIVO DE LOS PLASTICOS DE UN SOLO USO AL AÑO 2021.

Law that regulates the integral process of solid waste:
QUE REGULA LA GESTION INTEGRAL DE RESIDUOS EN LA REPUBLICA DE PANAMA COMO TEMA ESENCIAL DE SALUD PUBLICA.

Appendix B: Translated Copies of Law Documents

Relevant translated laws from Law 41 of 1998:

From Law 41 Established on June 1 of 1998, digitized per the national assembly of September 8, 2016

English Summary

Artículo 4. Son principios y lineamientos de la Política Nacional de Ambiente los siguientes:

1. Dotar a la población, como deber del Estado, de un ambiente saludable y adecuado para la vida y el desarrollo sostenible.
2. Definir las acciones gubernamentales y no gubernamental es en el ámbito local, regional y nacional, que garanticen la eficiente y efectiva coordinación intersectorial, para la protección, conservación, mejoramiento y restauración de la calidad ambiental.
3. Incorporar la dimensión ambiental en las decisiones, acciones y estrategias económicas. sociales y culturales del Estado, así como integrar la Política Nacional de Ambiente al conjunto de políticas públicas del Estado.
4. Promover comportamientos ambientalmente sostenibles y el uso de tecnologías limpia,. así como estimular acciones de reducción, reutilización, reciclaje y recuperación de desechos y apoyar la conformación de un mercado que aproveche sosteniblemente tales actitudes.
5. Dar prioridad a los mecanismos e instrumentos para la prevención de la contaminación y la restauración ambiental, en la gestión pública y privada de ambiente, divulgando información oportuna para promover el cambio de actitud.
6. Dar prioridad y favorecer los instrumentos y mecanismos de promoción. estímulos e Incentivos, en el proceso de conversión del sistema productivo, hacia estilos compatibles con los principios consagrados en la presente Ley.
7. Incluir, dentro de las condiciones de otorgamiento a particulares derechos sobre recursos naturales, la obligación de compensar ecológicamente por los recursos naturales utilizados y fijar, para estos fines, el valor económico de dichos recursos, que incorpore su costo social y de conservación.
8. Promover mecanismos de solución de controversias, como mediación, arbitraje. conciliación y audiencias públicas.
9. Destinar los recursos para asegurar la viabilidad económica de la Política Nacional de Ambiente.
10. Promover medidas preventivas y reactivas, públicas y privadas, autónomas o planificados para que la población y los ecosistemas se adapten al cambio climático. Asimismo, establecer los incentivos necesarios para facilitar la transición del Estado hacia una economía baja en carbono.

Principles and guidelines of the National Environment Policies are the following

1.) It's the states duty to protect the environment

2.) Establish governmental and non-governmental laws at the local, regional, and national level which protect the environment

3.) Consider the environment in any economic, social, or cultural decisions so that you comply with the public policies

4.) Promote sustainable lifestyles and use clean technology to stimulate environmentally friendly tendencies

5.) Adopt methods to educate the public about environmental protection to promote 'green' attitudes

6.) Prioritize methods (in reference to the above guideline) of stimulating green behaviors which are compatible with the current law

7.) Within a legal grant to a particle natural resource, affix an economic value which incorporates social and conservatory costs of said resource

8.) Sponsor conflict-resolution (as it relates to the aforementioned terms) through mediation, arbitration, or public audiences

9.) Appraise resources according to the National Environmental Policy

10.) Establish measures that will allow the population and ecosystem to adapt to climate change. Also, establish incentives to facilitate a transition towards a reduced carbon economy.

Artículo 6. El Ministerio de Ambiente promoverá el establecimiento del ordenamiento ambiental del territorio nacional y velará por los usos del espacio en función de sus aptitudes ecológicas. sociales y culturales, su capacidad de carga, el inventario de recursos naturales renovables o no renovables y las necesidades del desarrollo, en coordinación con las autoridades competentes. El ordenamiento ambiental del territorio nacional se ejecutará en forma progresiva por las autoridades competentes, para propiciar las acciones tendientes a mejorar la calidad de vida. Las actividades que se autoricen no deberán perjudicar el uso o función prioritaria del área respectiva, identificada en el Programa de Ordenamiento Ambiental del Territorio Nacional.

The Environment Ministry will promote the establishment of environmental acts imposed by local governments and will watch for the uses of land and the impact on its ecology, social structure, culture, and presence of natural resources.

Artículo 9. El proceso de evaluación de impacto ambiental incluirá mecanismos de participación ciudadana y comprenderá las etapas siguientes:

1. la presentación. Ante el Ministerio de Ambiente, de un estudio de impacto ambiental, según se trate de actividades, obras o proyectos, contenidos en la lista taxativa de la reglamentación de la presente Ley, cuyos requisitos, categoría y contenidos sean de conformidad a dicha reglamentación.
2. Ia revisión del estudio de impacto ambiental por el Ministerio de Ambiente.
3. La aprobación o rechazo del estudio de impacto ambiental por el Ministerio de Ambiente.
4. El seguimiento, control, fiscalización y evaluación de la ejecución del Plan de Manejo Ambiental y del estudio de impacto ambiental aprobado del contenido de la resolución de aprobación.

The laws regulating the process of evaluating environmental impact allow for civic participation which must observe the following steps [in order to occur]:

1.) Propose a study, before the Environmental Ministry, to perform. This study must observe procedures and regulations detailed by the law.
2.) Revise this study if the Environmental Ministry tells you to
3.) The study will be approved or rejected
4.) This study must occur in a controlled manner in accordance with the clauses established in the initial approval of the study.

Artículo 25. La supervisión, el control y la fiscalización de las actividades, obras y proyectos sujetos a la evaluación de impacto ambiental quedan sometidos a la presentación del Plan de Manejo Ambiental y al cumplimiento de las normas ambientales. Esta es una función inherente al Ministerio de Ambiente, la cual será ejercida junto con la autoridad competente de acuerdo con el reglamento, según sea el caso.

The supervision, control, and fiscalization of activities, jobs, or projects subject to evaluation for their environmental impacts are subject to having to present an Environmental Management Plan and to compliance with environmental law. This is an inherent function of the Environmental Ministry which will be exercised in cooperation with competent authority in accordance with the regulations.

Articulo 26. Las inspecciones y auditorías ambientales podrán ser aleatorias o conforme a programas aprobados por el Ministerio de Ambiente, y solo podrán ser realizadas por personas naturales o jurídicas debidamente certificadas por el Ministerio. Quienes presten servicios de inspectoría o auditoría ambientales estarán sometidos, para estos efectos, a las responsabilidades previstas en la legislación vigente.

Environmental inspections and audits can be random or routine per programs approved by the Environmental Ministry, and can be carried out by people certified by the ministry. Whoever provides environmental inspection or audit services will be subject to responsibilities established in the current legislation.

Artículo 30. El Sistema Nacional de Información Ambiental tiene por objeto recopilar, sistematizar, almacenar y distribuir información ambiental de los recursos naturales y de sostenibilidad ambiental del territorio nacional, entre los organismos y dependencias, públicos y privados, de forma idónea, veraz y oportuna, sobre las materias que conforman el ámbito del Sistema Interinstitucional de Ambiente y que son necesari as para la conservación ambiental y uso sostenible de los recursos naturales. Esta información es de libre acceso. Los particulares que la soliciten asumirán el costo del servicio.

The objective of the National System of Environmental Information is to compile, systemize, store, and distribute environmental information about natural resources and about environmental sustainability of national territory, between organizations and agencies, public and private, in the ideal form, accurate and convenient, about matters within the sphere of the Interinstitutional Environment System and those which are necessary for environmental conservation and the sustainable use of natural resources. This information is open access. Those who request this information assume the associated costs of the services.

Put simply, they have all the information and anyone can access it but you also have to pay for it.

Artículo 33. Son deberes del Estado difundir información o programas sobre la conservación del ambiente y el aprovechamiento sostenible de los recursos naturales, así como promover actividades educativas y culturales de índole ambiental, para contribuir a complementar los valores cívicos y morales

en la sociedad panameña, los medios de comunicación podrán ofrecer su colaboración para el cumplimiento de la proyección del presente artículo.

The dissemination of information or programs related to environmental conservation and the appropriate use of natural resources is a duty of the state. The purpose of this is to promote education and cultural activities related to the environment, in order to encourage civic and moral values in Panamanian society.

Artículo 35. El Ministerio de Ambiente otorgará, en los casos que se ameriten, reconocimientos ambientales para las personas naturales o jurídicas que dediquen esfuerzos a la educación ambiental.

The Environmental Ministry will grant, in cases which merit it, environmental awards for those who dedicate effort to environmental education.

Artículo 42. El Estado creará las condiciones legales y financieras para la inversión, pública o privada, en sistemas de tratamiento de aguas residuales con fines de reutilización, siempre que con ello no se afecten la salubridad pública ni los ecosistemas naturales. El El Estado regulará estos servicios.

The state will create legal conditions and finances for the public or private investment in water-waste treatment systems so that public health or natural ecosystems are not affected

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Artículo 43. Es deber del Estado, a través de la autoridad competente, regular y controlar el manejo diferenciado de los desechos domésticos, industriales y peligrosos, en todas sus etapas, comprendiendo, entre éstas, las de generación, recolección, transporte, reciclaje y disposición final. El Estado establecerá las tasas por estos servicios.

It is a duty of the State, through the competent authority, to regulate and control the defined use of domestic, industrial, and dangerous waste. They must cover all aspects of this process including generation, recollection, transportation, recycling, and the final disposing of waste. The state will establish taxes for these services.

Artículo 68. Los usuarios que aprovechen los recursos hídricos están obligados a realizar

las obras necesarias para su conservación, de conformidad con el Plan de Manejo Ambiental y el contrato de concesión respectivo.

Those that use the water must make an effort to conserve it.

Artículo 69. El Ministerio de Ambiente creará programas especiales de manejo de cuencas, en las que, por el nivel de deterioro o por la conservación estratégica, se justifique un manejo descentralizado de sus recursos hídricos por las autoridades locales y usuarios.

The Environmental Ministry will create programs to manage the watersheds through local authorities if there is significant deterioration in the water level or for conservation purposes.

Artículo 91. El Estado panameño reconoce el valor que para la gestión ambiental tiene la iniciativa privada que protege y aprovecha los recursos naturales de manera sostenible. Para este fin, El Ministerio de Ambiente impulsará mejores prácticas en materia de producción más limpia, eficiencia energética, construcción ecoeficiente, comunidades sostenibles, entre otras.

The Panamanian State will recognize the value of private initiatives to protect and make sustainable use of natural resources. For these ends, the environmental ministry will stimulate better practices regarding clean manufacturing, energy efficiency, eco-efficient construction, and sustainable communities, among other things.

Artículo 92. El Ministerio de Ambiente coordinará, con las autoridades tradicionales de las comarcas y pueblos indígenas, todo lo relativo al ambiente y a los recursos naturales existentes en sus territorios.

The Environmental Ministry will coordinate everything related to the environment and natural resources in indigenous towns in cooperation with their traditional authority.

Artículo 101. Toda persona natural o jurídica está en la obligación de prevenir el daño y controlar la contaminación ambiental.

Everyone’s responsible for protecting the environment

Artículo 102. La contaminación producida con infracción de los límites permisibles o de las nonnas, procesos y mecanismos de prevención, control, seguimiento, evaluación, mitigación y restauración, establecidos en la presente Ley y demás normas legales vigente, acarrea responsabilidad civil, administrativa o penal, según sea el caso.

Any contamination produced in a manner which goes against the current established law and other legal standards carries civil responsibility (administrative or penall), depending on the case.

Artículo 103. El que, mediante el uso o aprovechamiento de un recurso o por el ejercicio de una actividad, produzca daño al ambiente o a la salud humana estará obligado a reparar el daño causado, aplicar las medidas de prevención y mitigación y asumir los casos correspondientes.

Those who damage the environment by using a certain resource are obligated to contribute reparations in the form of costs associated with mitigation and prevention measures.

Articulo 104. Toda persona natural o jurídica que emita, vierta, disponga o descargue sustancias o desechos que afecten o puedan afectar la salud humana, pongan el riesgo o causen daño al ambiente, afecten o puedan afectar los procesos ecológicos esenciales o la calidad de vida de la población tendrá responsabilidad objetiva por los daños que puedan ocasionar graves perjuicios, de conformidad con lo que dispongan las leyes especiales relacionadas con el ambiente.

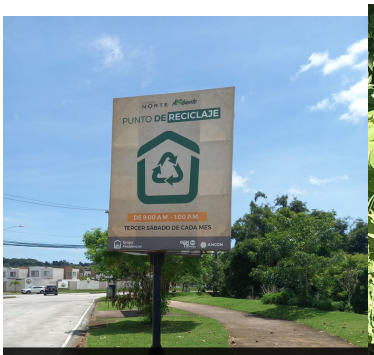
Anyone that emits, pours, displaces, or disposes of waste or substances which could potentially harm the environment or human health is responsible for damages they’ve caused according to the law.

Artículo 107. El incumplimiento de las normas de calidad ambiental, del estudio de impacto ambiental, su Plan de Manejo Ambiental o su resolución de aprobación, del Programa de Adecuación y Manejo Ambiental, de la presente Ley, las leyes y demás normas complementarias constituyen infracción administrativa. Dicha infracción será sancionada por el ministro de Ambiente con amonestación escrita y/o suspensión temporal o definitiva de las actividades de la empresa y/o multa, según sea el caso y la gravedad de la infracción, sin perjuicio de las sanciones principales y accesorias dispuestas en las normas complementarias existentes.

Failure, by those performing an environmental study, to comply with standards of environmental quality established in their Environmental Management Plan, in the terms of their study approval from the Environmental Management and Adaptation Program, by the current law and complementary standards, constitutes an administrative infraction. This infraction will be sanctioned by the Environmental Ministry with a written admonishment and/or temporary/permanent suspension of activities, according to the case and the severity of the infraction.

Appendix C: Ground Level Photos

Green Zone Category:



Paseo del Norte-I, Panamá

Latitude
9.0831316666666 67°

Longitude
-79.456625°

Local 12:15:41 p. m.
GMT 05:15:41 p. m.

Altitude 58,5 meters
domingo, 09-26-2021

Av. Urraca N 1 79, San Miguelito, Panamá

Latitude
9.059535°

Longitude
-79.440771666666 66°

Local 02:24:07 p. m.
GMT 07:24:07 p. m.

Altitude 40,2 meters
domingo, 09-26-2021

Calle de las Margaritas, San Miguelito, Panamá

Latitude
9.0691933333333 35°

Longitude
-79.439533333333 34°

Local 02:32:30 p. m.
GMT 07:32:30 p. m.

Altitude 33,1 meters
domingo, 09-26-2021

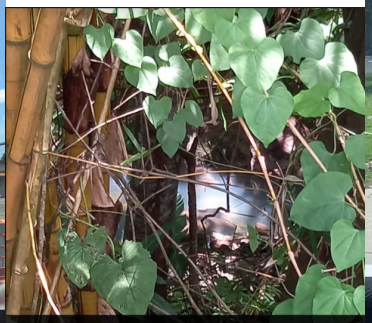
ZP Santa Librada - Puerta 1, San Miguelito, Panamá

Latitude
9.080926666666 667°

Longitude
-79.493766666666 67°

Local 11:31:01 a. m.
GMT 04:31:01 p. m.

Altitude 75,8 meters
domingo, 09-26-2021



Calle 11 Occidente 21, San Miguelito, Panamá

Latitude
9.069935°

Longitude
-79.456143333333 33°

Local 12:32:34 p. m.
GMT 05:32:34 p. m.

Altitude 54,1 meters
domingo, 09-26-2021

ZP Metro Cerro Viento-R - Puerta 3, Panamá

Latitude
9.05095°

Longitude
-79.449525°

Local 03:08:47 p. m.
GMT 08:08:47 p. m.

Altitude 27,3 meters
martes, 09-14-2021

Yellow Zone Category:

C. 3 4408-01, Panamá

Latitude	Longitude
9.042743333333334°	-79.44497666666666°
Local 02:55:52 p. m. GMT 07:55:52 p. m.	Altitude 27,8 meters martes, 09-14-2021

Calle a 2, Panamá

Latitude	Longitude
9.087715°	-79.49249°
Local 10:49:03 a. m. GMT 03:49:03 p. m.	Altitude 61,9 meters domingo, 09-26-2021

C. 3 3704, Panamá

Latitude	Longitude
9.045396666666667°	-79.44546333333332°
Local 02:43:02 p. m. GMT 07:43:02 p. m.	Altitude 29,5 meters martes, 09-14-2021

C. 9a 9, Panamá

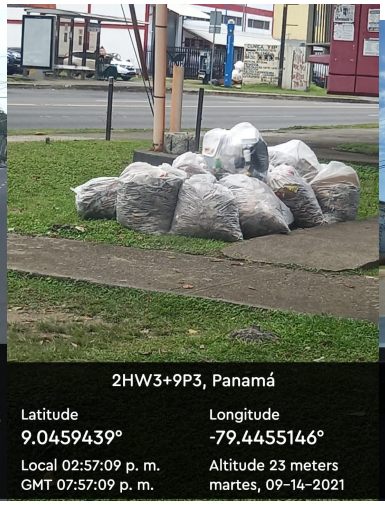
Latitude	Longitude
9.0966417°	-79.4967974°
Local 10:44:42 a. m. GMT 03:44:42 p. m.	Altitude 102,5 meters domingo, 09-26-2021

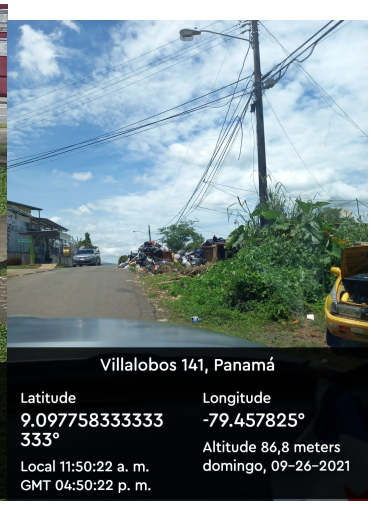
Manzana 080823 116335-5, Panamá

Latitude	Longitude
9.10077°	-79.49103833333334°
Local 10:30:08 a. m. GMT 03:30:08 p. m.	Altitude 90,4 meters domingo, 09-26-2021

Calle a 1, Panamá

Latitude	Longitude
9.097433333333333°	-79.49672666666667°
Local 10:43:57 a. m. GMT 03:43:57 p. m.	Altitude 103,6 meters domingo, 09-26-2021





Red Zone Category:

Calle C12 12, Panamá

Latitude
9.092706666666666°

Longitude
-79.49590166666667°

Local 10:46:39 a. m.
GMT 03:46:39 p. m.

Altitude 76,6 meters
domingo, 09-26-2021

Cerro Viento-I, San Miguelito, Panamá

Latitude
9.050176666666665°

Longitude
-79.45530666666667°

Local 03:10:38 p. m.
GMT 08:10:38 p. m.

Altitude 26,5 meters
martes, 09-14-2021

Corredor de los Pobres 140678-6, Panamá

Latitude
9.099548333333333°

Longitude
-79.50456666666668°

Local 10:34:20 a. m.
GMT 03:34:20 p. m.

Altitude 77,5 meters
domingo, 09-26-2021

Manzana 081007 128310-2, San Miguelito, Panamá

Latitude
9.083625000000001°

Longitude
-79.49181333333333°

Local 11:01:36 a. m.
GMT 04:01:36 p. m.

Altitude 84,2 meters
domingo, 09-26-2021

C. Villalobos 7, Panamá

Latitude
9.083879999999999°

Longitude
-79.44344°

Altitude 51,3 meters
domingo, 09-26-2021

Calle 2110 2110, San Miguelito, Panamá

Latitude
9.078813333333333°

Longitude
-79.4916°

Altitude 84 meters
domingo, 09-26-2021

Local 11:11:13 a. m.
GMT 04:11:13 p. m.

Manzana 081007 128849-3, San Miguelito, Panamá

Latitude
9.087555°

Longitude
-79.49228666666666°

Local 11:34:59 a. m.
GMT 04:34:59 p. m.

Altitude 63,6 meters
domingo, 09-26-2021

Cerro Viento-I, San Miguelito, Panamá

Latitude
9.050176666666665°

Longitude
-79.45530666666667°

Local 03:10:50 p. m.
GMT 08:10:50 p. m.

Altitude 26,5 meters
martes, 09-14-2021

6ta G Sur 186, San Miguelito, Panamá

Latitude
9.039868333333335°

Longitude
-79.44301833333334°

Local 02:52:15 p. m.
GMT 07:52:15 p. m.

Altitude 29,1 meters
martes, 09-14-2021

Villalobos 145, Panamá

Latitude
9.09793°
Local 11:51:23 a. m.
GMT 04:51:23 p. m.

Longitude
-79.46039166666667°
Altitude 70,9 meters
domingo, 09-26-2021

Manzana 081007 154723, San Miguelito, Panamá

Latitude
9.081674999999999°
Local 11:14:40 a. m.
GMT 04:14:40 p. m.

Longitude
-79.49338333333334°
Altitude 74,6 meters
domingo, 09-26-2021

3GJV+757, Panamá

Latitude
9.080195°
Local 12:18:10 p. m.
GMT 05:18:10 p. m.

Longitude
-79.45688333333332°
Altitude 51,7 meters
domingo, 09-26-2021

Corredor de los Pobres 204, Panamá

Latitude
9.094375000000001°
Local 11:59:57 a. m.
GMT 04:59:57 p. m.

Longitude
-79.455895°
Altitude 82,6 meters
domingo, 09-26-2021

2HQ4+XV3, Panamá

Latitude
9.039875°
Local 02:51:25 p. m.
GMT 07:51:25 p. m.

Longitude
-79.44287°
Altitude 28,6 meters
martes, 09-14-2021

Calle 1010 1010, Panamá

Latitude
9.088276666666667°
Local 11:35:32 a. m.
GMT 04:35:32 p. m.

Longitude
-79.49183°
Altitude 53,8 meters
domingo, 09-26-2021

Av. José Agustín Arango 2000, Panamá

Latitude
9.046335°
Local 02:31:01 p. m.
GMT 07:31:01 p. m.

Longitude
-79.45298166666666°
Altitude 30,9 meters
martes, 09-14-2021

Av. José Agustín Arango 2000, Panamá

Latitude
9.046335°
Local 02:31:06 p. m.
GMT 07:31:06 p. m.

Longitude
-79.45298166666666°
Altitude 30,9 meters
martes, 09-14-2021

Manzana 081007 154723, San Miguelito, Panamá

Latitude
9.081471666666665°
Local 11:14:53 a. m.
GMT 04:14:53 p. m.

Longitude
-79.49347333333334°
Altitude 71 meters
domingo, 09-26-2021

Manzana 081007 128580-2, San Miguelito, Panamá

Latitude
9.086283333333334°
Local 11:33:42 a. m.
GMT 04:33:42 p. m.

Longitude
-79.491785°
Altitude 59,2 meters
domingo, 09-26-2021

Manzana 081007 141024-6, San Miguelito, Panamá

Latitude
9.086096666666666°
Local 10:53:35 a. m.
GMT 03:53:35 p. m.

Longitude
-79.49202166666667°
Altitude 64,2 meters
domingo, 09-26-2021

Manzana 081007 128849-1, San Miguelito, Panamá

Latitude
9.08649°
Local 11:33:50 a. m.
GMT 04:33:50 p. m.

Longitude
-79.491700000000001°
Altitude 59 meters
domingo, 09-26-2021

Manzana 081007 128602-1, San Miguelito, Panamá

Latitude
9.083498333333333°
Local 11:01:18 a. m.
GMT 04:01:18 p. m.

Longitude
-79.491595°
Altitude 78,9 meters
domingo, 09-26-2021

Corredor de los Pobres 140678-6, Panamá

Latitude
9.099548333333333°
Local 10:34:05 a. m.
GMT 03:34:05 p. m.

Longitude
-79.50456666666668°
Altitude 77,5 meters
domingo, 09-26-2021

Manzana 081007 128849-8, San Miguelito, Panamá

Latitude
9.087031666666666°
Local 11:34:26 a. m.
GMT 04:34:26 p. m.

Longitude
-79.491675°
Altitude 58,8 meters
domingo, 09-26-2021

6c Nte. 23, Panamá

Latitude
9.044821666666667°
Local 02:01:23 p. m.
GMT 07:01:23 p. m.

Longitude
-79.46208166666666°
Altitude 31,6 meters
domingo, 09-26-2021

Manzana 080823 116335-5, Panamá

Latitude
9.10077°
Local 10:31:01 a. m.
GMT 03:31:01 p. m.

Longitude
-79.49103833333334°
Altitude 90,4 meters
domingo, 09-26-2021

Manzana 081007 128849-3, San Miguelito, Panamá

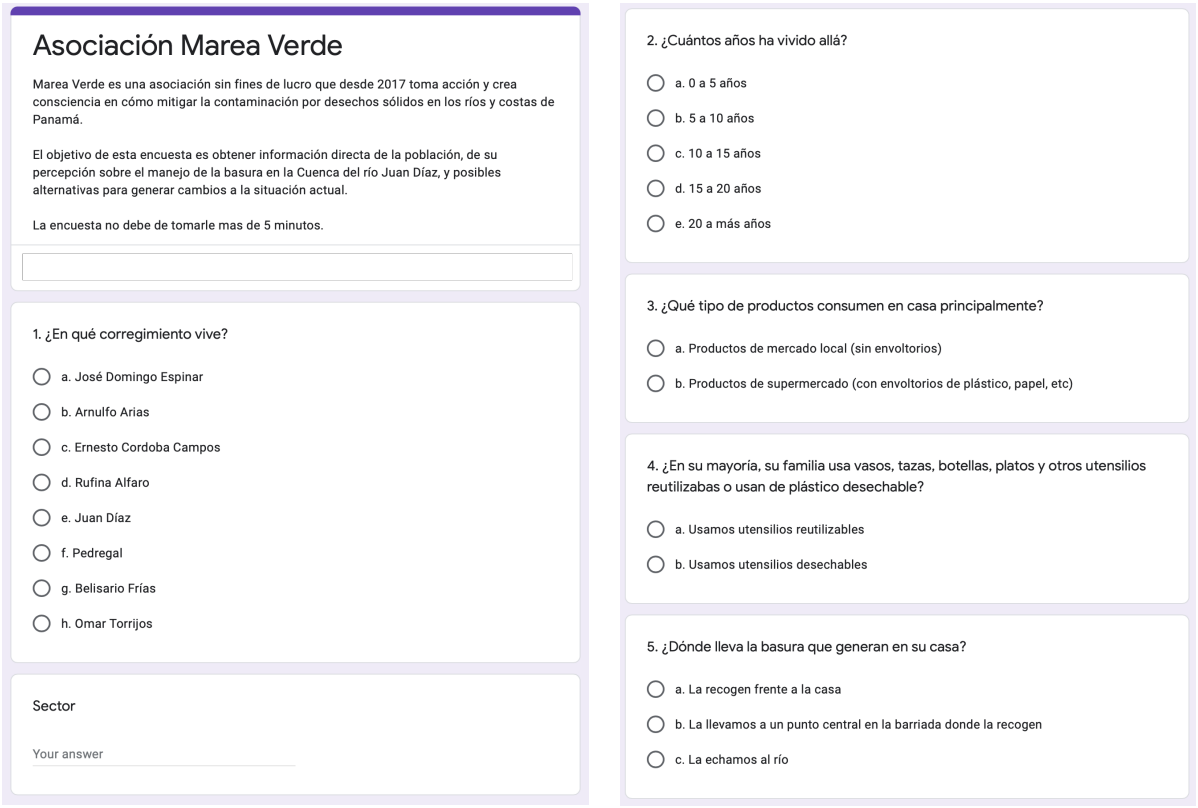
Latitude
9.087555°
Local 11:34:59 a. m.
GMT 04:34:59 p. m.

Longitude
-79.49228666666666°
Altitude 63,6 meters
domingo, 09-26-2021


Avenida Domingo Díaz, en dirección al Aeropuerto, frente a Office Depot de Brisas del Golf, Panamá
Latitude
9.048156666666667°
Longitude
-79.46129666666667°
Local 02:21:03 p. m.
GMT 07:21:03 p. m.
Altitude 28,7 meters
martes, 09-14-2021

Appendix D: Juan Diaz River Watershed Survey

Original (Spanish) Version:



Asociación Marea Verde

Marea Verde es una asociación sin fines de lucro que desde 2017 toma acción y crea consciencia en cómo mitigar la contaminación por desechos sólidos en los ríos y costas de Panamá.

El objetivo de esta encuesta es obtener información directa de la población, de su percepción sobre el manejo de la basura en la Cuenca del río Juan Díaz, y posibles alternativas para generar cambios a la situación actual.

La encuesta no debe de tomarle mas de 5 minutos.

1. ¿En qué corregimiento vive?

- a. José Domingo Espinar
- b. Arnulfo Arias
- c. Ernesto Cordoba Campos
- d. Rufina Alfaro
- e. Juan Díaz
- f. Pedregal
- g. Belisario Frías
- h. Omar Torrijos

Sector

Your answer

2. ¿Cuántos años ha vivido allá?

- a. 0 a 5 años
- b. 5 a 10 años
- c. 10 a 15 años
- d. 15 a 20 años
- e. 20 a más años

3. ¿Qué tipo de productos consumen en casa principalmente?

- a. Productos de mercado local (sin envoltorios)
- b. Productos de supermercado (con envoltorios de plástico, papel, etc)

4. ¿En su mayoría, su familia usa vasos, tazas, botellas, platos y otros utensilios reutilizabas o usan de plástico desechable?

- a. Usamos utensilios reutilizables
- b. Usamos utensilios desechables

5. ¿Dónde lleva la basura que generan en su casa?

- a. La recogen frente a la casa
- b. La llevamos a un punto central en la barriada donde la recogen
- c. La echamos al río

6. ¿Ud. considera que la recolección de la basura es un problema para su comunidad?

- ○ a. Tremendo problema
- ○ b. Es un problema menor
- ○ c. No es un problema

7a. ¿Ud. separa los residuos sólidos para poder reciclar algunos? (Si responde "siempre" o "a veces", proceder con la pregunta 7b. Si responde "nunca", saltar a la pregunta 8.)

- ○ a. Siempre
- ○ b. A veces
- ○ c. Nunca

7b. ¿Qué materiales recicla?

- ☐ a. Plástico
- ☐ b. Vidrio
- ☐ c. Metal
- ☐ d. Papel / cartón

8. ¿Ud. cree que un proyecto de reciclaje ayudaría a reducir el problema de basura en la comunidad?

- ○ a. Si
- ○ b. No
- ○ c. No sé

9. ¿Sabe Ud. dónde queda la quebrada o río más cercano a su casa?

- ○ a. Claro que sí
- ○ b. No estoy seguro/a

Si contestó que si, ¿Cuál es el nombre de esa quebrada o río?

Your answer

¿Sabe a qué distancia en metros queda la quebrada o río de su casa? Si sí, por favor llenar este campo (si no sabe, pasar a la siguiente pregunta)

Your answer

10. ¿Cómo usa Ud. la quebrada o río?

- [ ] a. Espacio para recreo en las orillas
- [ ] b. Espacio para descansar y charlar con amigos
- [ ] c. Pescamos
- [ ] d. Nos bañamos
- [ ] e. Sacamos agua para uso doméstico
- [ ] f. Lavamos ropa y platos
- [ ] g. Tiramos basura
- [ ] h. No hacemos ningún uso de la quebrada

11. En comparación con hace 5 años, cómo califica el estado de la quebrada o río hoy:

- ○ a. Mejor
- ○ b. Lo mismo
- ○ c. Peor

Por favor especifique: limpieza, olor, volumen de agua

Your answer

English Translation:

Marea Verde Association

Marea Verde is a non-profit association that since 2017 has been acting and raising awareness on how to mitigate solid waste pollution on the rivers and coasts of Panama.

The objective of this survey is to obtain direct information from the population, their perception of garbage management in the Juan Díaz River Basin, and possible alternatives to generate changes to the current situation.

The survey should not take you more than 5 minutes.

1. What District are you from?
    a. José Domingo Espinar
    b. Arnulf Arias
    c. Ernesto Cordoba Campos
    d. Rufina Alfaro
    e. Juan Díaz
    f. Pedregal
    g. Belisario Frías
    h. Omar Torrijos

1b. What Sector?

2. How many years have you lived there?
    a. 0 to 5 years
    b. 5 to 10 years
    c. 10 to 15 years
    d. 15 to 20 years old
    e. 20 to more years
3. What kind of products do you consume mainly at home?
    a. Local market products (without packaging)
    b. Supermarket products (with plastic wrappers, paper, etc.)
4. For the most part, does your family use disposable plastic cups, bottles, plates, and other utensils?
    a. We use reusable utensils
    b. We use disposable utensils
5. Where do you take the garbage generated in your house?
    a. They pick it up in front of the house
    b. We take it to a central point in the neighborhood where it is picked up
    c. We throw it into the river
6. Do you consider garbage collection a problem for your community?
    a. Tremendous problem
    b. It's a minor problem
    c. It's not a problem
7. Do you separate solid waste so that some can be recycled? (If you answered "always" or "sometimes", proceed with question 7b. If you answered "never", skip to question 8.)
    a. Always
    b. Sometimes
    c. Never

7b. What materials do you recycle?

    d. Plastic
    e. Glass
    f. Metal
    g. Paper / cardboard

8. Do you think a recycling project would help reduce the garbage problem in the community?
    a. Yes
    b. No
    c. I don't know
9. Do you know where the stream or river closest to your house is?
    a. Of course
        i. If you answered yes, what is the name of that river?
            1. Do you know how far in meters the river is from your house? If yes, please fill in this field (if you don't know, move on to the next question)
    b. I'm not sure
10. How do you use the river?
    a. Recreational space on the shores
    b. Space to rest and chat with friends
    c. We fish
    d. We bathe
    e. We draw water for domestic use
    f. We wash clothes and dishes
    g. We throw garbage
    h. We don't make any use of the river
11. Compared to 5 years ago, what is the state of the river today:
    a. Better
    b. The same
    c. Worse

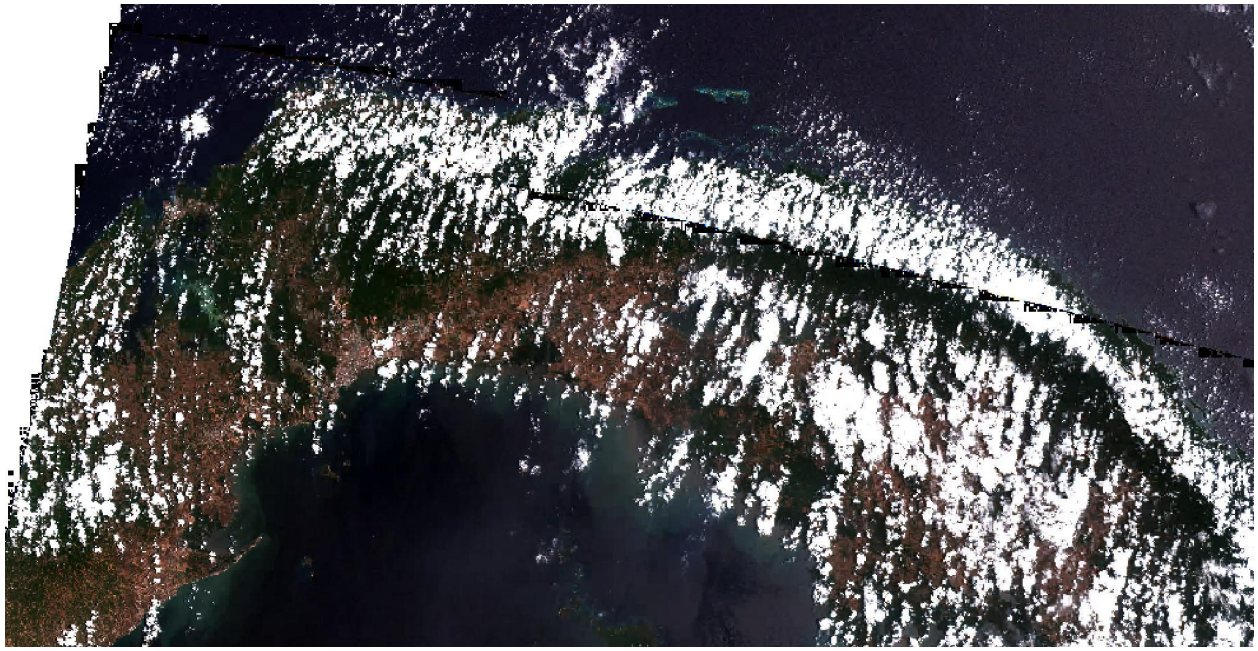
11b. Please specify cleanliness, smell, and volume of water

12. Can the contamination of the river by plastics, garbage and sewage cause severe impacts on the human health of your neighborhood?
    a. Of course
    b. No
    c. I don't know

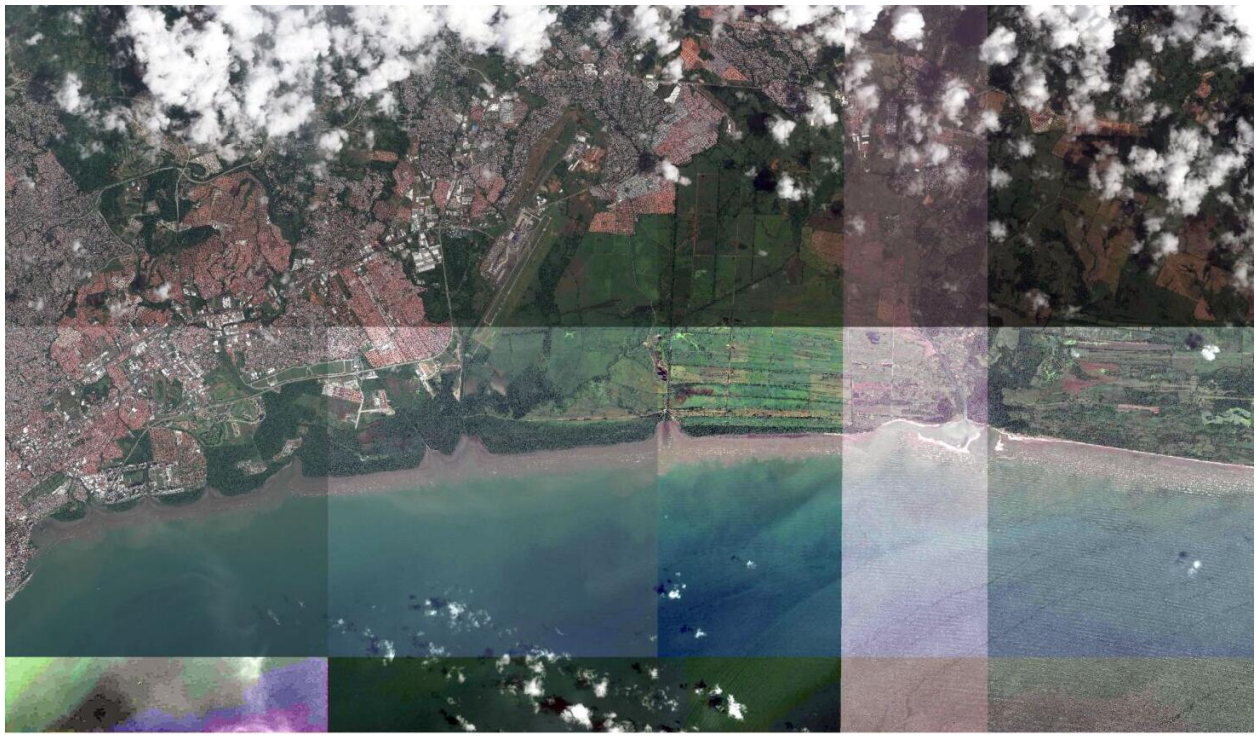
13. Can pollution of the river by plastics, garbage and sewage cause severe impacts on the beach and the sea?
    a. Of course
    b. No
    c. I don't know
14. Would you be interested in participating in a study group on these topics?
    a. Yes
    b. No

Appendix E: Recent and Older Satellite Images

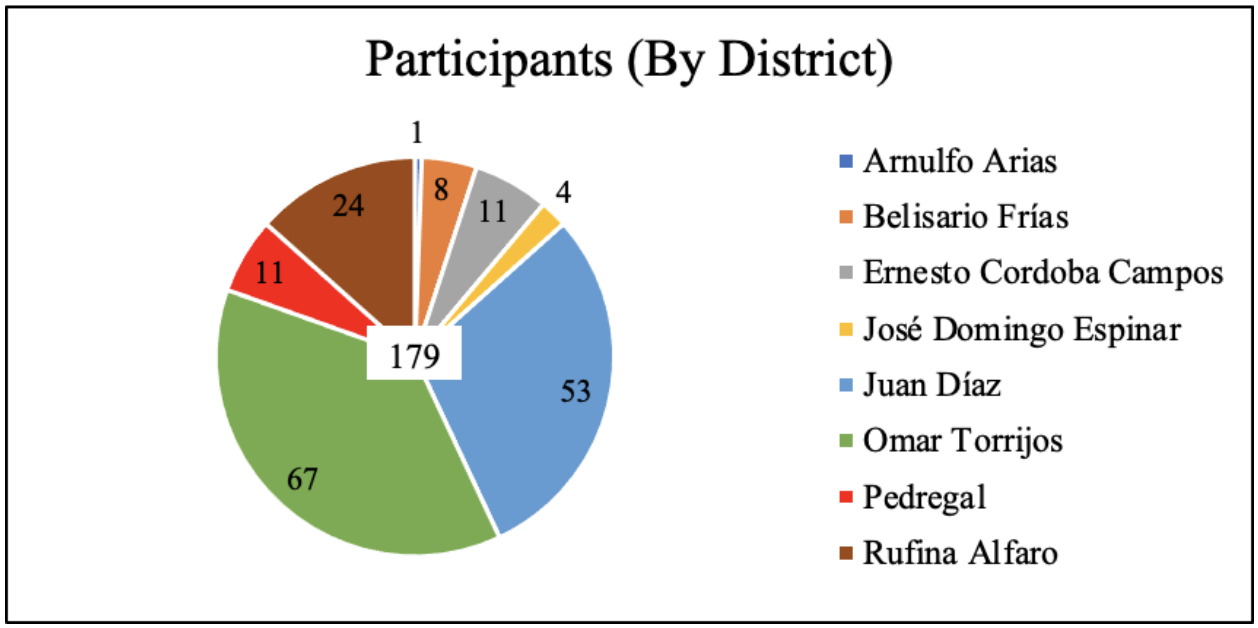
April 2016 Image:

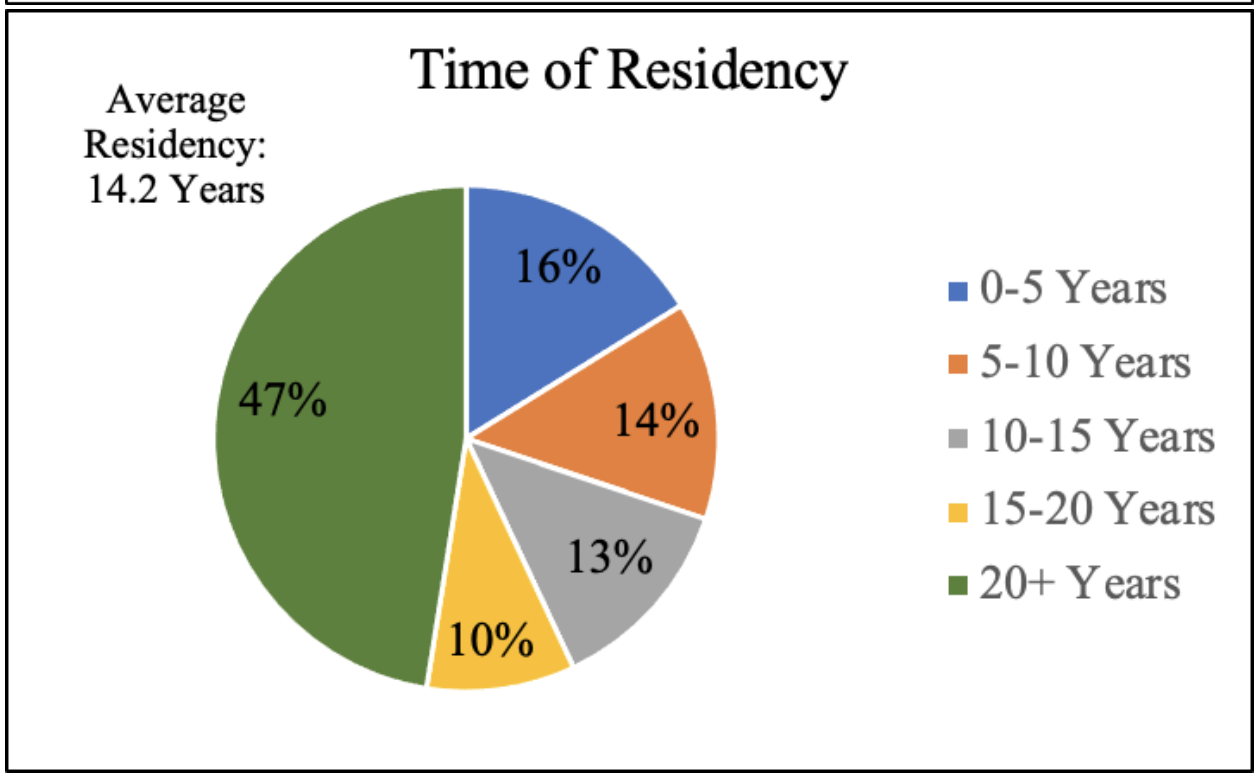


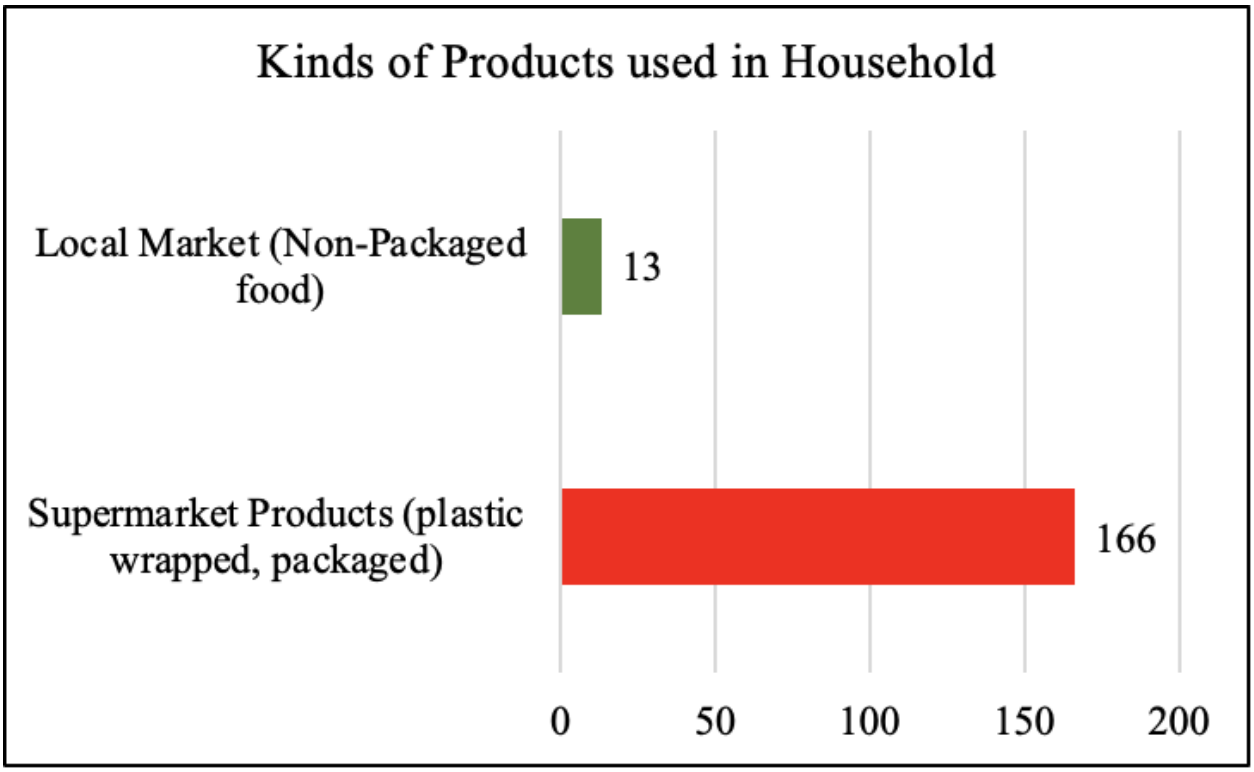
February 2021 Image:

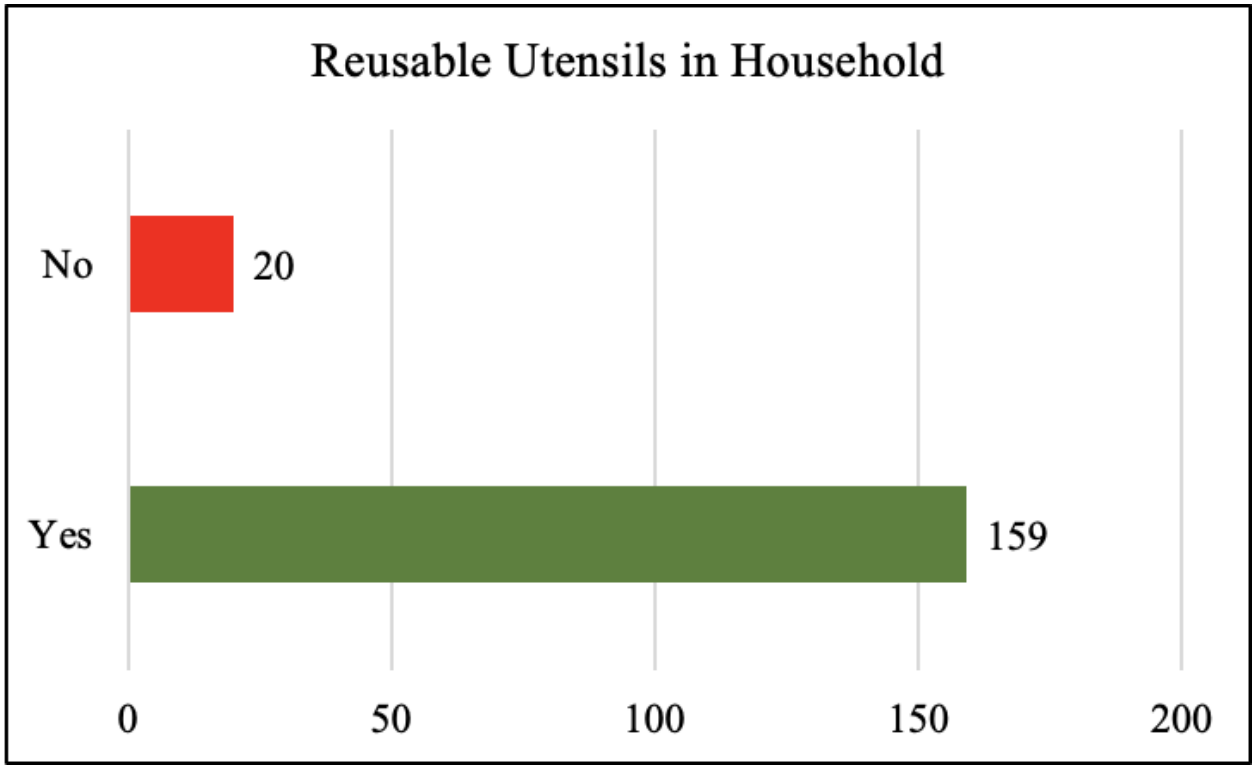


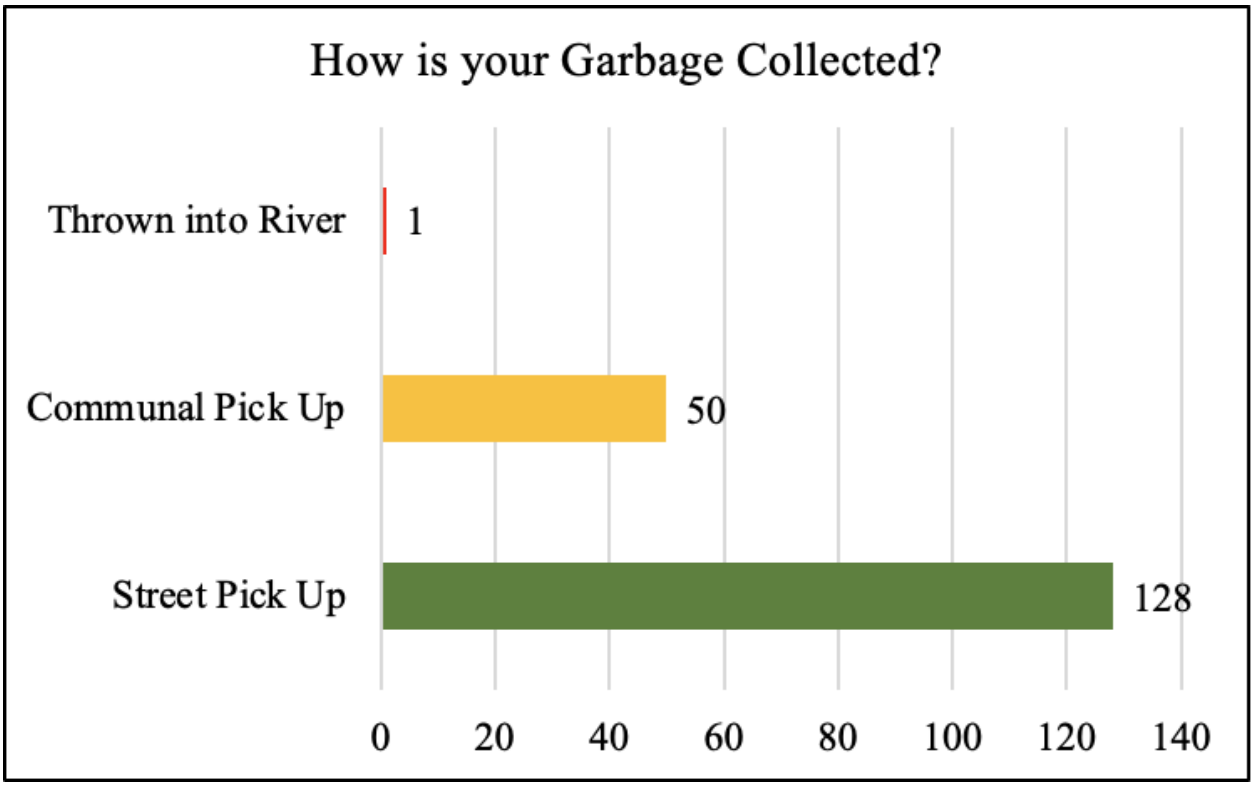
Appendix F: Survey Result Graphics

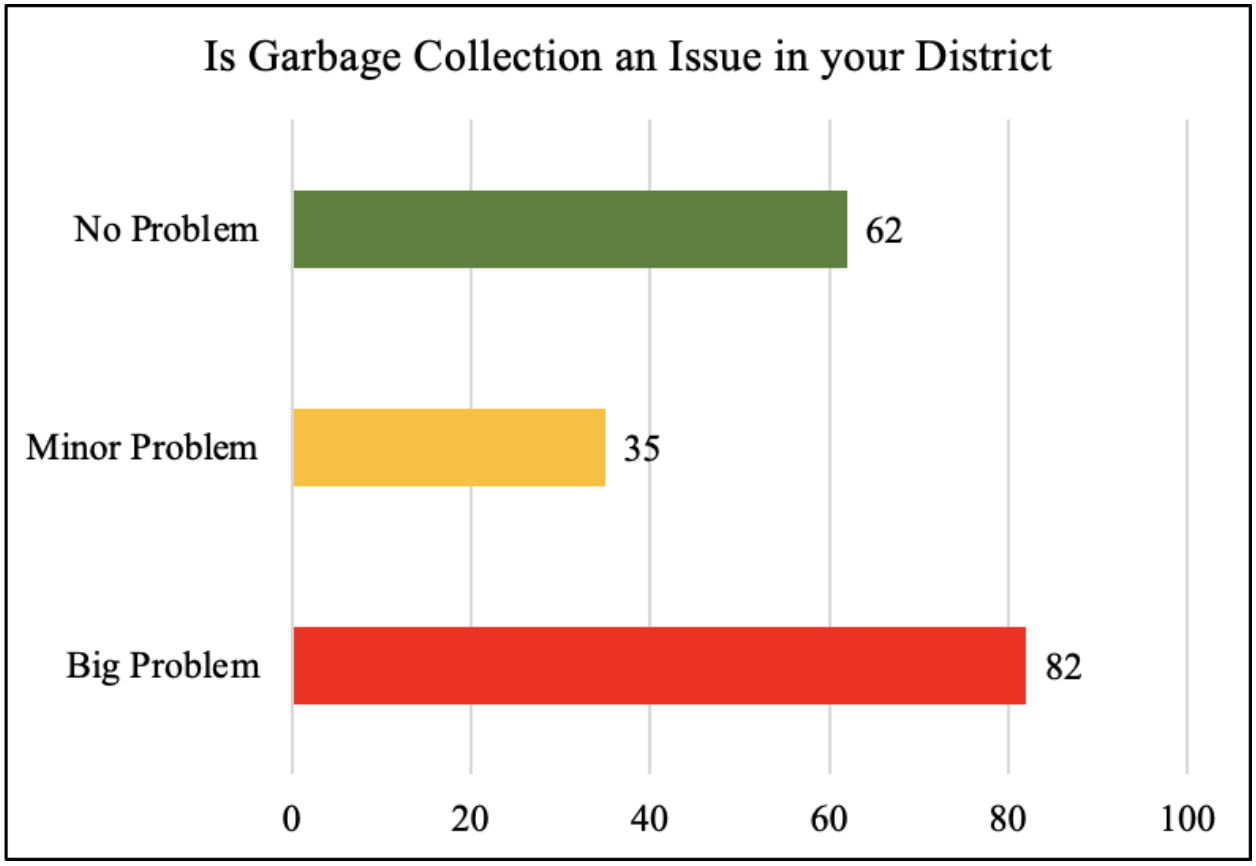


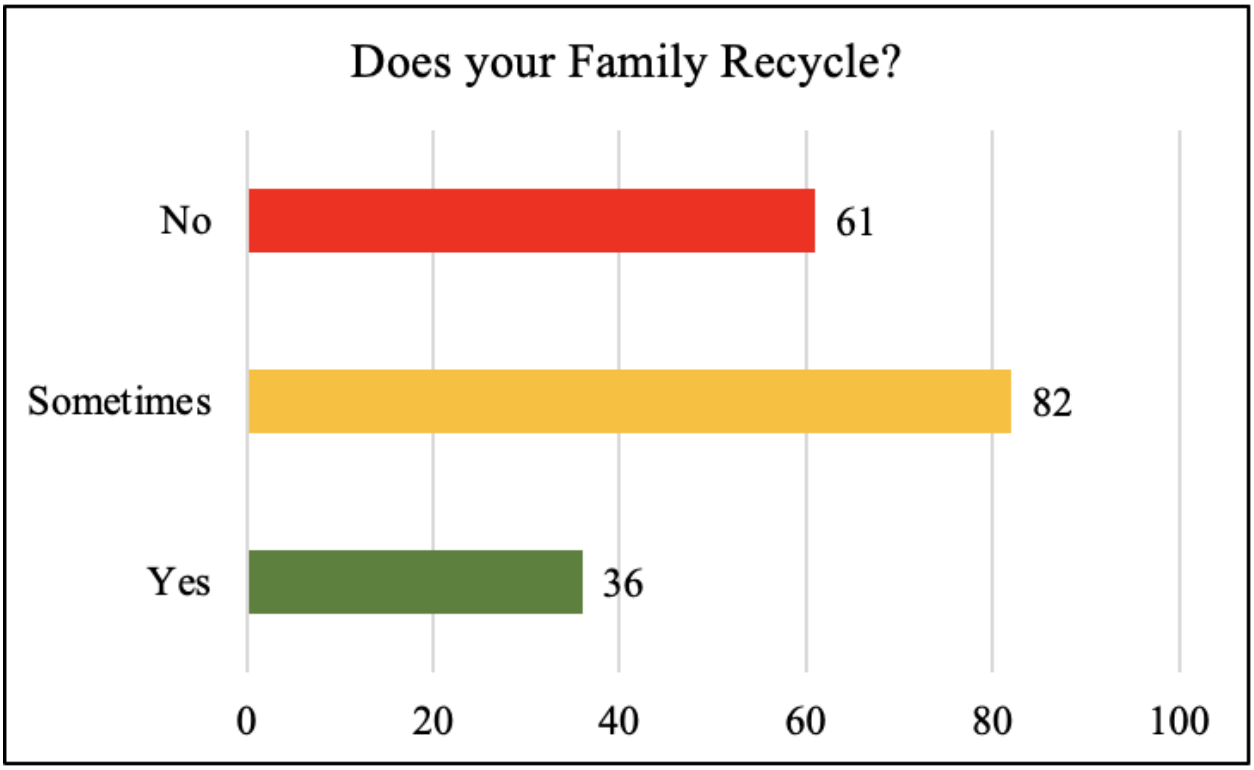


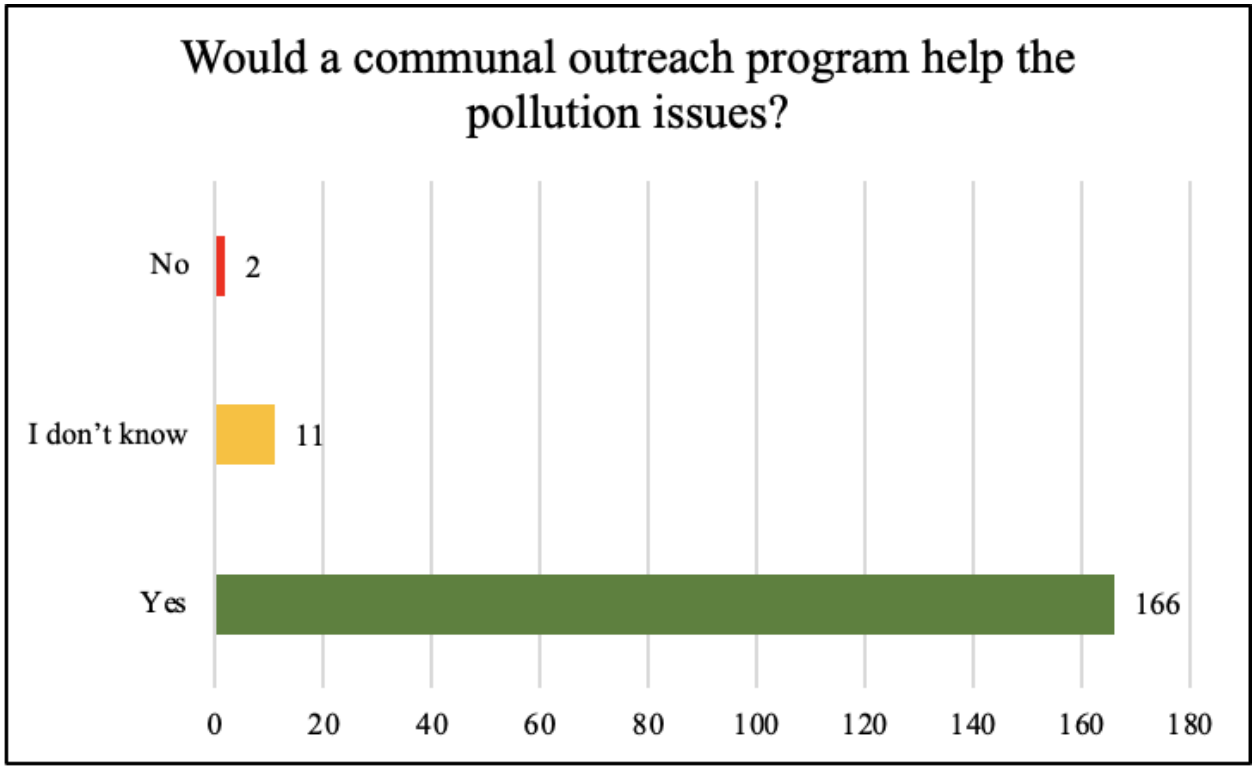

Kinds of Products used in Household
Local Market (Non-Packaged food)
13
Supermarket Products (plastic wrapped, packaged)
166
0
50
100
150
200

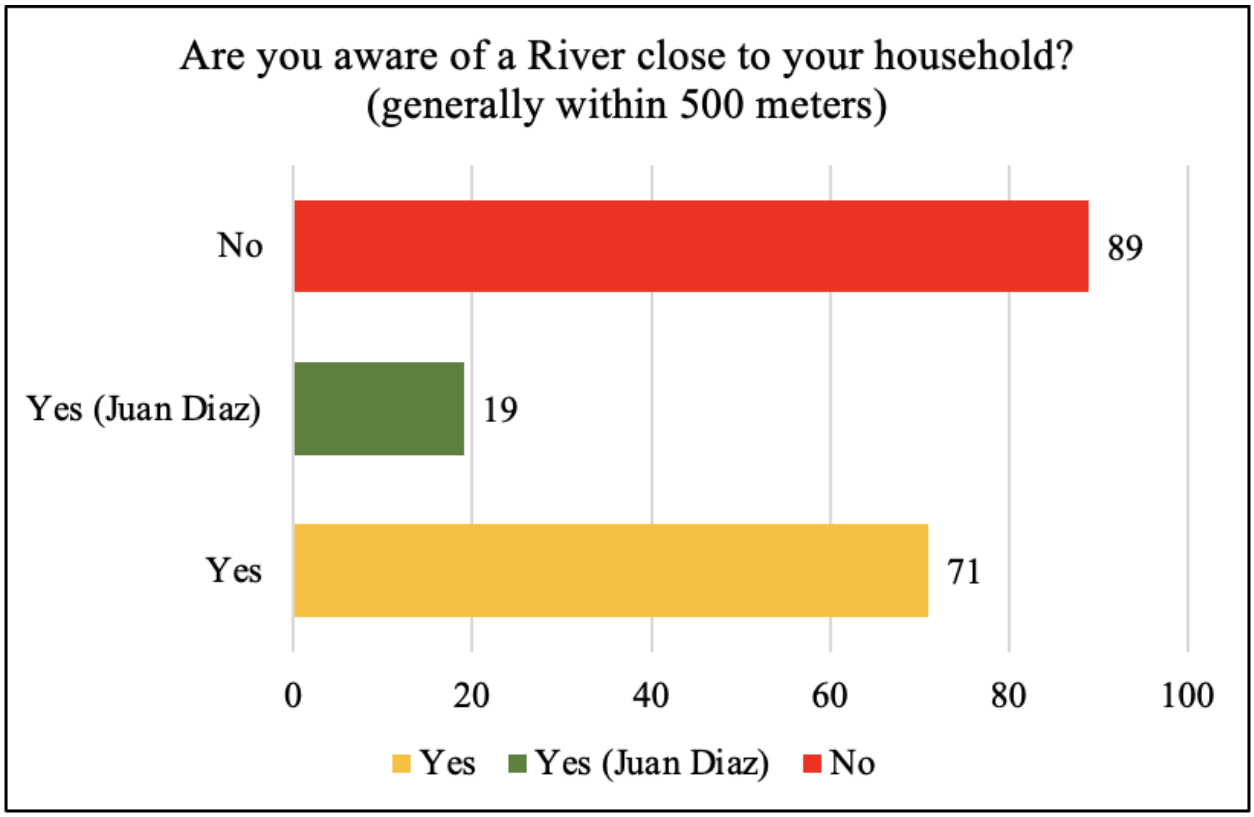

Reusable Utensils in Household
No
20
Yes
159
0
50
100
150
200

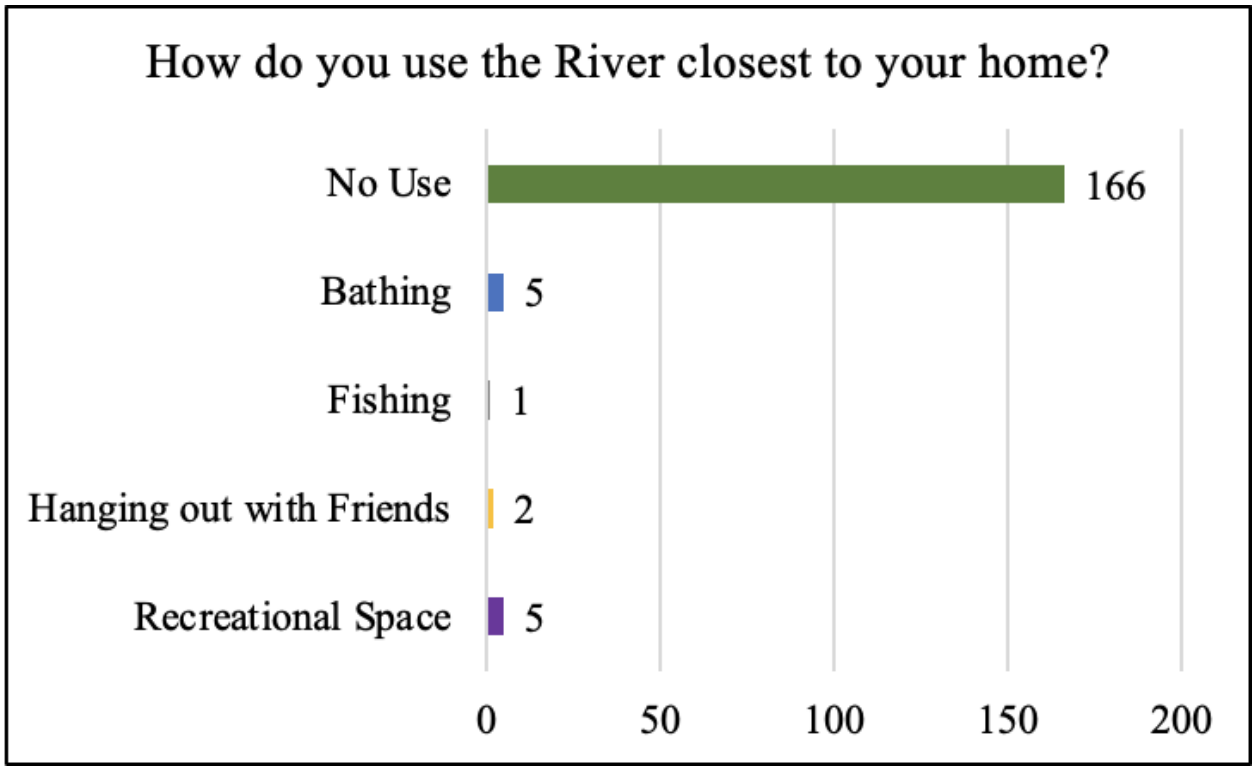

How is your Garbage Collected?
Thrown into River
1
Communal Pick Up
50
Street Pick Up
128
0
20
40
60
80
100
120
140

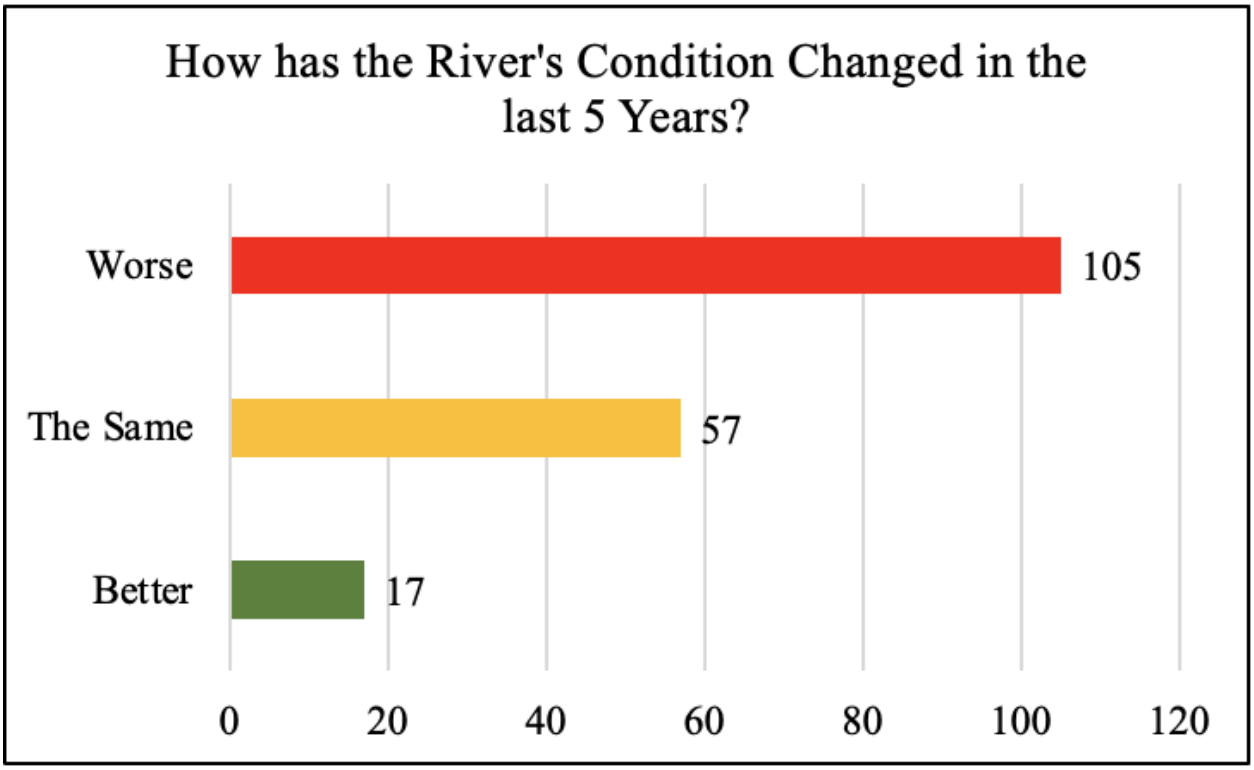

Is Garbage Collection an Issue in your District
No Problem
62
Minor Problem
35
Big Problem
82
0
20
40
60
80
100

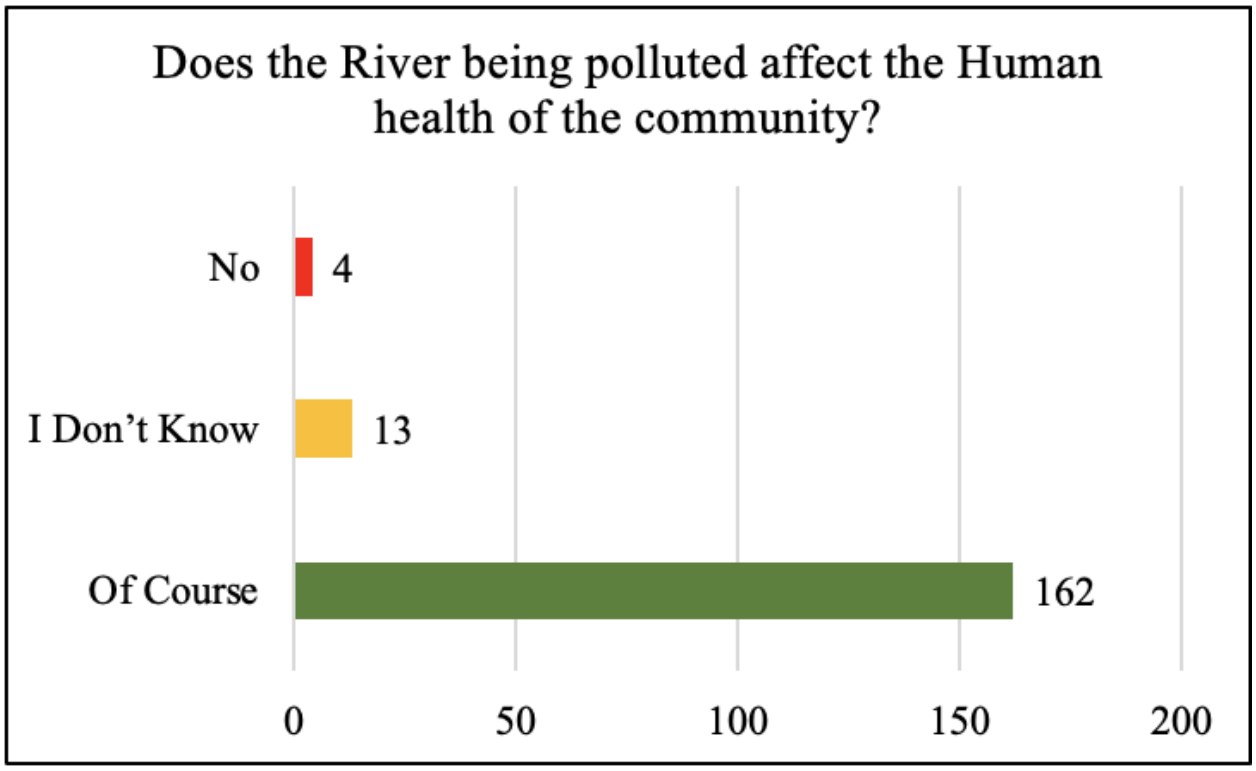

Does your Family Recycle?
No
61
Sometimes
82
Yes
36
0
20
40
60
80
100

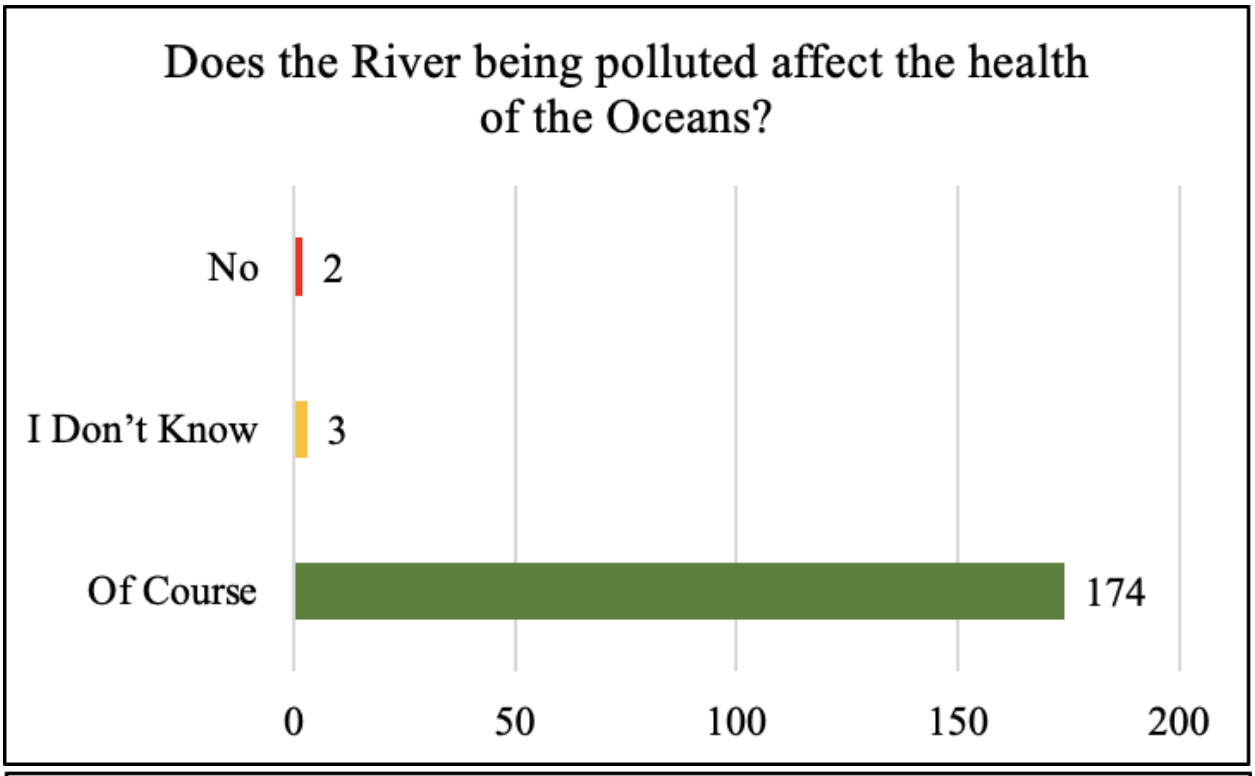

Would a communal outreach program help the pollution issues?
No
2
I don't know
11
Yes
166
0
20
40
60
80
100
120
140
160
180

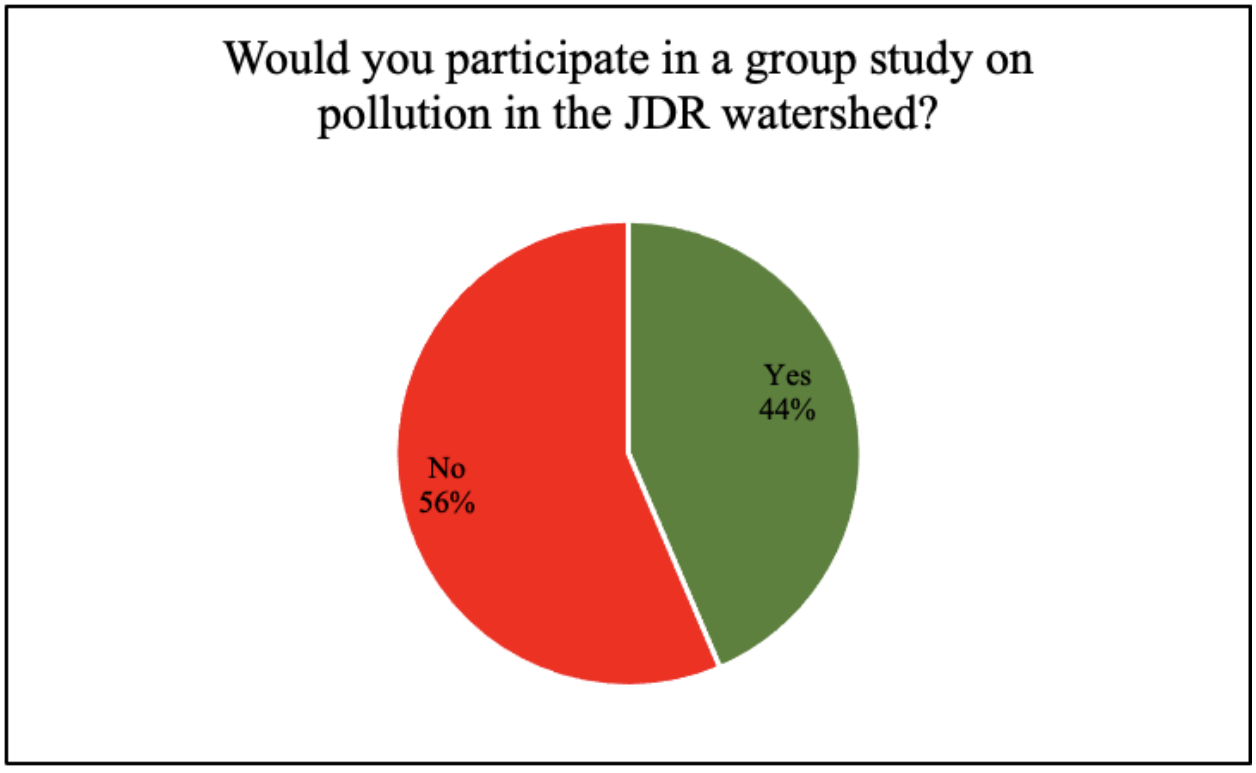

Are you aware of a River close to your household?
(generally within 500 meters)
No
89
Yes (Juan Diaz)
19
Yes
71
0
20
40
60
80
100
Yes
Yes (Juan Diaz)
No


How do you use the River closest to your home?
No Use
166
Bathing
5
Fishing
1
Hanging out with Friends
2
Recreational Space
5
0
50
100
150
200


How has the River's Condition Changed in the last 5 Years?
Worse
105
The Same
57
Better
17
0
20
40
60
80
100
120


Does the River being polluted affect the Human health of the community?
No
4
I Don't Know
13
Of Course
162
0
50
100
150
200


Does the River being polluted affect the health of the Oceans?
No
2
I Don't Know
3
Of Course
174
0
50
100
150
200


Would you participate in a group study on pollution in the JDR watershed?
Yes
44%
No
56%