Annex 3A. Characterization Form for Defining the Costs and Benefits of Domestic Wastewater Management – Isla Colon, Panama

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STUDY SITE: **Isla Colon, Bocas del Toro, Panama**

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RESPONDENT INFORMATION

This report was completed by:

Name: Erin Gray, Lauretta Burke, and L. Jasmine Lambert, World Resources Institute

Organization: World Resources Institute

Date: August 12, 2015 – *Note: This document reflects the understanding of the study site through this date. Since August 12, 2015, the future wastewater management scenario has been updated for Isla Colon. The future wastewater section of this form details this new scenario as a footnote.*

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Contents:

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I. DEFINE THE STUDY AREA

Objective: Define and map the study area including key geographic and land use data to identify wastewater pollution and other water pollution pathways and populations of interest.

Possible data sources: National environmental, water, and/or marine agencies; non-profit organizations (NGOs); academic institutes with marine/environmental centers that conduct research within the study site.

1. Please define the study area by providing a detailed description.

The study area should include the sewage catchment name(s) and geographic area, the populated area to be served by improved wastewater treatment, the area downstream which is expected to be influenced by the change in wastewater management (including receiving water bodies (e.g., rivers, lakes, oceans) and water catchments, and the upstream catchment (which might be contributing pollutants to the water body of focus).

The selected study site area is the island of Isla Colon in Bocas del Toro Province. Isla Colon is the most populated island of the archipelago of Bocas del Toro. The island is divided into a northern and southern section by a small isthmus. Most development is centered in Bocas Town located in the southern part of the island. The northern part of the island is primarily forest with some development, including new residential development. The Bocas del Toro archipelago is divided into two semi-closed lagoons – the Chiriqui Lagoon and the Bahia de Almirante.

The introductory Ministry of Environment (MdA) and World Resources Institute (WRI) workshop (MdA and WRI 2014) confirmed the following as important beaches and locations:

- Beaches: Itsmito Beach (also known as La Feria), Big Creek, Bluff, Mimitibi, Bocas del Drago, Starfish.
- Other important locations: Main Park, Governor's Building, Hotel Bahia, Airport, Hospital, Cemetery, La Feria, Bluff, La Gruta bat cave, Bocas del Drago.

The Bocas del Toro archipelago is also divided into two semi-closed lagoons – the Chiriqui Lagoon and the Bahia de Almirante.

2. Can you put it on a map? (with GIS; Google Earth; or participatory mapping)

If possible, indicate on a map the information provided in Question 1. This can be done in GIS, using Google Earth, and/or working with stakeholders using a participatory mapping approach to highlight on a hard copy map the response to Question 1.

We currently do not have GIS data – but have the following maps:

Figure 1: Wikipedia (2015) image of the Archipelago of Bocas del Toro

Figure 2: Bahia Almirante Map from Seemann et al. 2014

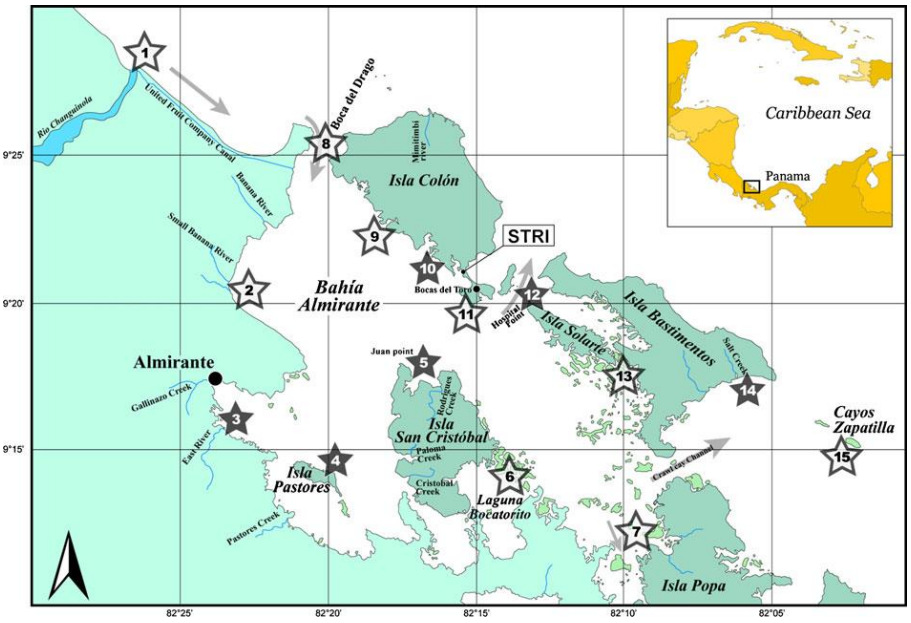


Figure 3: Google Earth image of Isla Colon (left) and Bocas town and Isla Carenero (right)

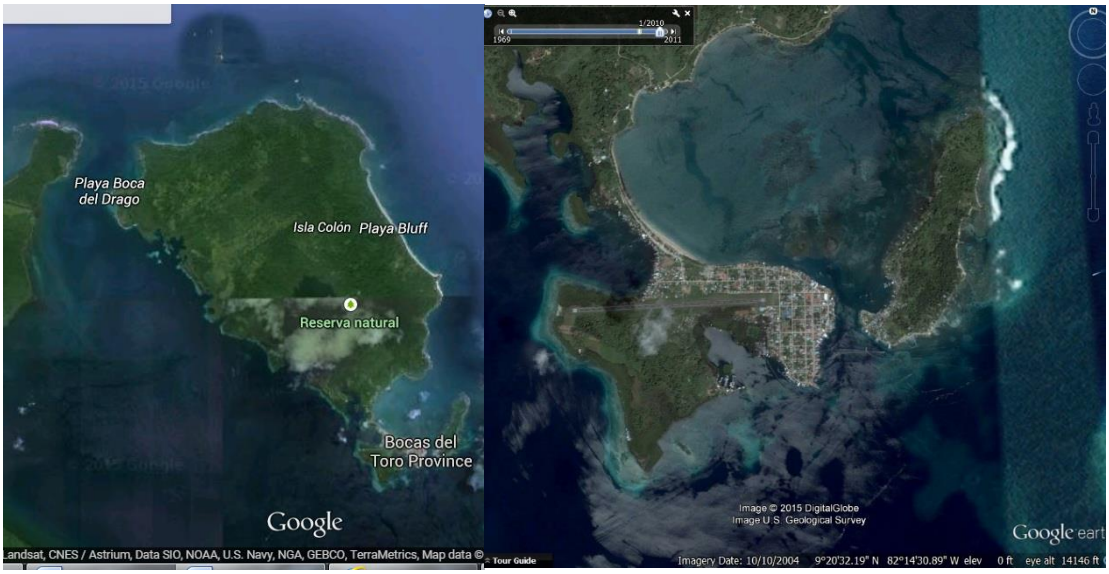
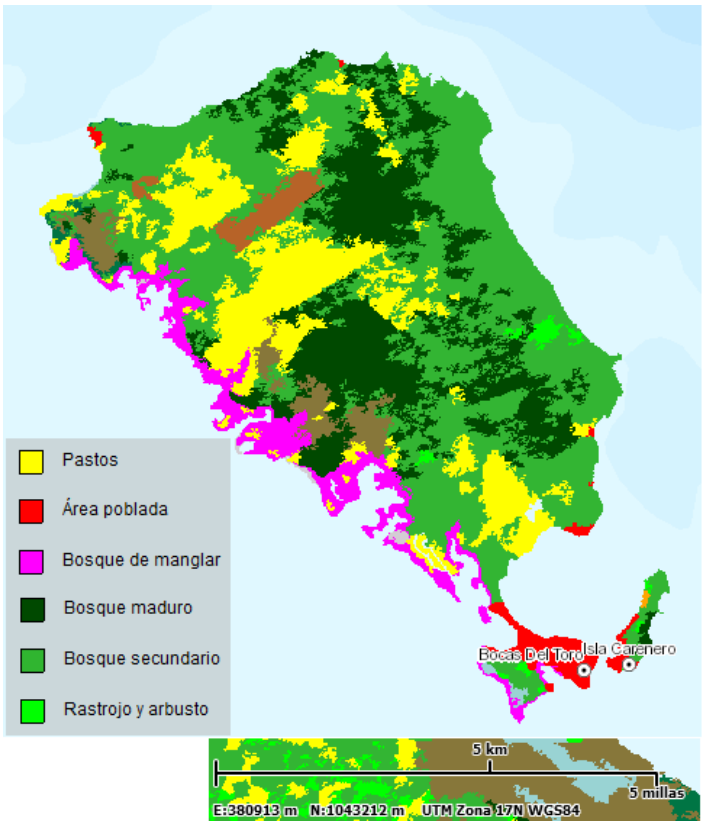


Figure 4: Spatial map of Terrain



*Adapted from 2012 Map of Coverage, Ministry of the Environment (2012)

3. What are the major land uses (such as residential, commercial, agricultural, open space / natural) in the study area?

- **Could you do rough estimates of percentages of each major land use?**

Based on stakeholder input from the introductory MdA and WRI workshop (2014), primary land uses include residential, commercial (including tourism), agriculture, forest, and informal indigenous settlements. There are about 523 indigenous families living in Bocas Town and their settlements have been constructed in the mangroves adjacent to the wastewater treatment facility (MdA and WRI 2015). The majority of development has happened south of the isthmus around Bocas Town. The northern section of the island above the isthmus appears to be primarily forest, some of which is primary forest, but there is also some residential development in this area.

Workshop participants stated that since the 1990s, there has been a sharp increase in tourism and associated infrastructure. For example, participants noted that the number of hotels on the island has risen from 6 to 40 over the past decade.

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II. POPULATION

Objective: Population data is critical for understanding current and future wastewater demand as well as the number of people who may swim in or eat from waters contaminated with untreated wastewater.

Possible data sources: Government census data; International population datasets from multilateral, intergovernmental, or NGOs (e.g., World Bank, United Nations).

1. How many people live in the study area? (Approximate if necessary.)

The province of Bocas del Toro has a population of 125,461 (INEC Panama 2010). Isla Colon is the most populated island in the Bocas del Toro archipelago. The main population center is Bocas Town, which as of 2008 had a population of 12,996 people (Wikipedia 2015). Additionally, according to 2010 Census Data there are 227 people living in Big Creek, 19 people living in Bluff, and 290 people living in Boca de Drago (INEC Panama 2010), giving an estimated total population of 13,532 for Isla Colon. Anecdotally, we have heard that the population of Isla Colon is closer to 15,0000.

Bocas Town has become a popular tourist destination with approximately 80,000 visitors per year (with 79,788 tourists in 2014 and 77,714 tourists in 2013 and a 3 % annual growth rate in tourism in the past two years. Tourists are mostly coming from Europe, the United States, Panama, and Asia (MdA 2015b).

2. Can you disaggregate this by neighborhood / area / housing development / smaller administrative unit?

No.

3. How many households are in the study area? (Approximate if necessary)

The average size of household in Panama is roughly 4.4 people (UN Stats 1995), so a rough estimate of the total number of households in Isla Colon would be ~3,400 assuming a population of 15,000 people.

There are approximately 523 indigenous families living 2-3 families per house) living in Bocas Town (MdA and WRI 2015).

4. What is the population projection for the study area over the next 20, 30, and/or 50 years (for each period if data are available)?

The annual population growth rate for Panama is two percent (World Bank 2015), so the population projection based on this figure is:

- Current (2015): 15,000
- In 20 years (2035): 22,289
- In 50 years (2065): 29,998

However, the rate is likely lower for Isla Colon as many nationals live on the mainland and travel by boat to Isla Colon for work. Participants of the Mda and WRI workshop (2015) stated that the expatriate population, however, is growing on the island.

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III. ECONOMIC ACTIVITIES

Objective: Economic data are important for understanding the economic activities that are important for the local economy that rely on ecosystems (especially those potentially impacted by water pollution).

Possible data sources: Government census data; International population datasets from multilateral, intergovernmental, or NGOs (e.g., World Bank, United Nations).

1. **Are the following sectors important for the local economy (ideally for the study area)? Can you estimate the relative contribution from each sector to the local economy? If quantitative data are not available, please rate the sector's importance based on the following scale:**

   Importance Scale:
   - **Not important:** The sector is not relevant as it does not contribute much to local GDP (e.g., through jobs or financial contribution)
   - **Moderate importance:** The sector is important, but is not the main contributor to local GDP.
   - **Very important:** The sector contributes substantially to local GDP.
   - **Critical:** The sector contributes the largest amount of any sector to local GDP

- **Tourism? (Note types of tourism)**
- **Agriculture? (Note types of agriculture)**
- **Fisheries? (Note major fish species)**
- **Industry? (Note what industry/ies)**
- **Other?**

Historically, the economy of Isla Colon was based largely on agriculture, namely, banana plantations. Today, the island's economy is based mostly on tourism – primarily ecotourism. Eco-tourism activities include (MdA and WRI 2014 & 2015; Frommers 2015):

- Recreational beaches (Starfish Beach, Sandfly Beach, Big Creek Beach, Boca del Drago, and Bluff Beach)
- Boat tours to surrounding tourism spots
- Bird Island – a small rocky outcropping off the northern tip of Isla Colon, famous for birdwatching. It's the only place in Panama to see the Red-Billed Tropicbird.
- Surfing
- Scuba diving and snorkeling

The commercial sector has been built up around tourism and includes a local airport, local restaurants, hotels, handicrafts, bicycle rentals, and tours. Fishing and limited agriculture are still practiced on the island (small cattle, banana farming, and subsistence farming). The island is also home to the Smithsonian Tropical Research Institute, which attracts scientists, students and tourists alike.

In addition to tourism, the island hosts a significant number of yachts and cruise ships each year.

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IV. KEY ECOSYSTEMS

Objective: To understand potential benefits to ecosystem health from wastewater management improvements, it is necessary to a) identify key ecosystems in the study sites, b) their economic contribution in terms of key goods and services they provide, c) their contribution to key economic sectors. This will help to characterize the dependence of these sectors on healthy ecosystems, and as a result, the value of these ecosystems to the study population and the nation.

Possible data sources: Government environmental/water/natural resource agencies or ministries; Academic institutes and environmental NGOs conducting research or working towards the protection or conservation of ecosystems; Peer-reviewed and grey literature on key ecosystem both within and outside of the study area; Government reports including environmental impact statements, water quality permits, or benefit-cost analyses;

1. **What are the key ecosystems in the study area (e.g., coral reefs, mangroves, seagrass beds, beaches, forests, wetlands), especially downstream from population, sewage discharge, or treated wastewater discharge? Key ecosystems are those which are important to the local economy or those which provide important cultural services.**

The Bocas del Toro archipelago is a complex chain of islands, mangrove cays, peninsulas, fringing reefs, and seagrass beds (Collin 2005). The archipelago is divided naturally into two semi-enclosed lagoons; the Chiriqui Lagoon is a turbid environment highly impacted from runoff, while Almirante Bay is less impacted by runoff (D'Croz et al. 2005). Silva (2015) states there are 60 species of coral in Panama, many of which can be found in Bocas del Toro. The Bahia de Almirante is a semilagoon system that has one main inlet at Boca del Drago and outlets between Isla Colón and Bastimentos, and another at the east of Isla Popa (see Fig. 1). It is bordered by large coastal swamps and mangrove forests (Seemann et al. 2014).

The national parks in the Province are Isla Bastimentos National Marine Park (Parque Nacional Marino Isla Bastimentos) and La Amistad International Park. The Isla Bastimentos National Marine Park contains most of Isla Bastimentos and some smaller nearby islands and extends into a large nature preserve at the Red Frog Beach Island Resort. La Amistad International Park (Parque Internacional La Amistad), spans the Costa Rica–Panama border. Bocas del Toro contains most of the Panamanian section of the

park and covers 400,000 hectares (4,000 km2; 1,544 sq mi). La Amistad International Park is a designated UNESCO World Heritage site (UNESCO 2015). It is not clear the extent to which pollution activities from Isla Colon impact these two national parks and ecosystems.

Beaches are important ecosystems for Isla Colon. For example, Playa Bluff, located on the east side of Isla Colon, is an important site for marine turtles during nesting season and is therefore a habitat that has the potential to be impacted by untreated wastewater effluent from the island (Chacon et al. 2015). Starfish beach, Sandfly beach, and Big Creek beach are popular for swimming and important habitats as well. Bocas del Drago is a popular snorkeling spot (Bocas del Toro Travel 2015).

Bird Island Isla Colon is a popular habitat for sea birds.

There are coral reefs and mangrove forests directly off the coast of Isla Colon, however, specific spatial information about the borders and extents of these ecosystems is still lacking. The mangroves are known for having a diverse ecosystem structure (CONADES 2008a).

2. **Please rank how important these ecosystems are to the economic sectors previously listed in Section III (within the study area) (e.g., is tourism in the area dependent on healthy ecosystems?). Please indicate in**
3. **Table 1 below the relative importance based on this scale:**

Importance Scale:

- **Not important**: The ecosystem has no relevance to the economic sector.
- **Moderate importance**: The economic sector is dependent on resources/services provided by the ecosystem but substitutes for natural resources are available (e.g., forest ecosystems provide water filtration services that can improve the health of fisheries, but water filtration systems are also available to filter water).
- **Very important:** The economic sector is dependent on the resources/services provided by the ecosystem and substitutes are not available or are exorbitantly expensive (e.g., mangroves provide important coastal protection services, guarding some shoreline industries from flooding and hurricanes. While options exist to improve coastal protection like dikes jetties, this type of infrastructure can be costly to build and maintain).
- **Critical:** The ecosystem is vital to the economic sector in that the sector would not profit or exist without the ecosystem (e.g., tourism in a coastal community may be completely dependent on coral reefs for scuba diving, snorkeling, and sand creation as these activities provide the most income to the local economy).

Table 1: Ranking of ecosystem important to key economic sectors

ECOSYSTEM	AGRICULTURE	FISHERIES	TOURISM	ACADEMIA*

Example: Coral reefs	*Not important*	*Critical*	*Very important*	*Very important*
Coral reefs	Not important	Critical	Critical	Critical
Mangroves	Not important	Critical	Moderate	Critical
Seagrasses	Not important	Very important	Moderate	Critical
Beaches	Not important	Moderate	Critical	Critical

4. **What goods and services do these key ecosystems provide (i.e., what are each of the ecosystems used by people for?). Please fill out**
5.
6.

7. **Table 2 below and add or delete ecosystems as needed. You may refer to**
8.

9. **Table 3, which provides a general list of ecosystem services for major Caribbean ecosystem types, for guidance.**

Table 2: Ecosystem goods and services

Ecosystem Goods and Services	CORAL REEFS	MANGROVES	BEACHES	SEAGRASSES
Food	X	X	X	X
Raw materials	X	X	X	X
Medicinal resources				
Genetic resources				
Flood/storm/erosion regulation	X	X	X	X
Climate regulation	X	X	X	X
Tourism and recreation	X	X	X	
History, culture, traditions	X	X	X	X
Science, knowledge, education	X	X	X	X
Primary production	X	X		X
Nutrient cycling	X	X		X
Species/ecosystem protection	X	X	X	X
Water filtration/supply	X	X		X

Table 3: Examples of coastal ecosystem goods and services

ECOSYSTEM GOODS AND SERVICES	CORAL REEFS	MANGROVES	BEACHES	SEAGRASSES
Provisioning services				
Food (e.g., fisheries)	X	X	X	X
Raw materials	X	X	X	X
Medicinal resources	X	X		X
Genetic resources	X	X		X
Regulating services				
Flood/storm/erosion regulation	X	X	X	X
Climate regulation	X	X	X	X
Cultural services				
Tourism and recreation	X	X	X	
History, culture, traditions	X	X	X	X
Science, knowledge, education	X	X	X	X
Supporting services				
Primary production	X	X	X	X
Nutrient cycling	X	X		X
Species/ecosystem protection	X	X	X	X

Source: WRI Coastal Capital Guidebook (Waite et al. 2013)

10. Are there any existing estimates of the economic values of these uses of ecosystems for this study area or nearby (e.g., through peer-reviewed or grey literature)? If so, please list these values, describe the methodology used to develop them, and provide a citation.

We are not aware of any existing estimates of the economic values of these uses of ecosystems for this study area or nearby areas. Based on our own calculations using data provided by the Tourism Authority of Panama (ATP 2015), the tourism industry in Isla Colon employs approximately 6,102 people on the island, which is nearly half the population, and tourists contribute approximately 1.8 million dollars in vacation spending annually.[1]

[1] Employment and spending approximations were calculated using the percentage of total tourists that visit Isla Colon as a percentage of total tourists in Panama for 2013 & 2014 based on information given by the Tourist Authority of the Republic of Panama. This percentage was then used to calculate the relative ratio of people employed by the tourism industry based on national figures. Likewise, Isla Colon tourist population data was applied to national averages on tourist spending per visit to estimate the amount of money spent by tourists over the course of one year in Isla Colon. (Indicadores de Turismo de La Republica de Panamá, 2015)

11. **Do you have statistics on visitation / tourism (both foreign and national) to key ecosystems and/or statistics on visitation/tourism for the country for eco-tourism? For example, do you have data on the number of tourists (including cruise ship passengers, national and international tourists, and others) that visit the key ecosystems identified above?**

In 2013, 77,714 tourists visited Isla Colon, and in 2014, almost 80,000 tourists visited the island (and increase of 2.7%) (Ministry of Environment 2015).

There are 3 dive operators in Isla Colon that offer visits to some 17 different sites, the majority of which are inside of the Archipelago with some also at the Isla Bastimento.

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V. CURRENT WASTEWATER MANAGEMENT SITUATION

Objective: To understand how wastewater is currently treated within the study site to allow comparison against future wastewater management alternatives in terms of population served, untreated wastewater, pollution removal effectiveness for key pollutants, and capital and recurring costs.

Possible data sources: Wastewater authorities; Consultants or engineers that work with the wastewater authority; Environmental/water/natural resource agencies or ministries that issue wastewater permits; Wastewater experts; Historical costs; National price books.

1. **On-site wastewater treatment coverage:**
    - **Please estimate the percentage of the total domestic wastewater sector within the study that uses each type of on-site system below. For example: 30% of the total population uses on-site treatment. Of this 30%, 10% uses septic system, 10% uses pit latrines, and 10% uses soakaway systems).**
        - **Septic systems**
        - **Pit latrines**
        - **Soakaway systems**
        - **Other?**

Up to 20% of the population is not connected to the central wastewater treatment plant (WWTP). We remain unsure about whether the 20% of the population not connected to the treatment facility is using on-site treatment or not.

IDAAN has a five year investment plan for Panama under the 100/0 plan to bring 100% access to water and have 0 pit latrines by 2019. The 100/0 plan was established by President Juan Carlos Varela, by which a national priority was set to provide 100% of Panamian residents with access to drinking water (24 hours a day), and eliminate pit latrines. The Consejo Nacional de Desarrollo Sostenible (CONADES) helped create this plan and is working with IDAAN to realize its success.

- **What percentage of on-site systems (septic systems, pit latrines, soakaway systems, etc.) are properly maintained (i.e., regularly pumped out, drain fields not clogged, etc.)?**

Data not available.

2. **Wastewater collection system (i.e., sewerage):**
   - **Please describe the coverage of the current sewage collection system in terms of length of pipelines and the ultimate treatment point.**

There is no underground sewerage system, but rather a series of drainage networks.

3. **Please estimate the percentage of the total population and commercial and industrial establishments within the study that are connected to a centralized sewerage system.**

It is estimated that only 80% of the population in Bocas Town is connected to the wastewater treatment facility. However, the number of homes/businesses actually connected remains unknown. MdA and WRI workshop participants (2014) stated that they believe some development has been unregulated (namely Hotels), and that the number of new hotels connected to the plant is unknown. Zero of the 523 indigenous families are connected to the WWTP (IDAAN 2015).

4. **Wastewater treatment plants:**
   - **Please describe the number and type of wastewater treatment plants (WWTP) currently in place in the study area.**

In the 1980s, Isla Colon's wastewater treatment consisted of one oxidation lagoon, without an aeration system. Water was simply retained in the pond for 15-20 days and then released into the ocean. In 1991 there was a large earthquake that fractured the walls of the oxidation lagoon. IDAAN decided to divide the lagoon into two parts and only one part remained as an oxidation lagoon. In 2010 IDAAN installed an aeration system into the oxidation lagoon. Currently, only one of the two lagoons is functioning as an aeration (or oxidation) lagoon at a capacity of 3,055 m3/day and is meant to meet double the current population needs. There are a series of station pumps across Isla Colon that pump to the lagoons (IDAAN 2015). The capacity of the operational aeration lagoon is frequently exceeded during periods of high rainfall, resulting in the release of untreated sewage. In addition, the aeration pumps sometimes malfunction.

The challenges related to the state of current wastewater treatment on Isla Colon include (MdA and WRI 2014, 2015):

- The current wastewater treatment facility only treats residences and businesses up to the little isthmus and not the greater Isla Colon area (which is mostly forested, but is experiencing some development for homes and hotels). Additionally, it is estimated that only 80% of the population in

Bocas Town is connected to the facility. However, as previously stated, it is not known the number of homes/businesses actually connected.

- There could be some hotels with individual treatment plants but whether they are complying with regulations remains unknown.
- Restaurants do not have proper grease management (i.e., lack of compliance with regulations), which can get stuck and harden in pipes.
- Indigenous settlements are known to dump garbage directly into the sea and they lack fresh water and sanitation. Property prices are too high for many families to own or rent homes. It is thought that there is a high rate of infant mortality in these settlements. While the government cannot currently evacuate this population but is coming up with plans for resettlement and reforestation.
- There is no warning system for water contamination events and water quality is not monitored.
- The quality of potable water in the area is inadequate and water demand is growing with increasing tourism. There is some contamination of groundwater resources. There is currently not a drinking water treatment facility on the island (IDAAN 2014).
- There are zero ANAM lab technicians residing on Isla Colon; while water quality monitoring should be taking place, water quality monitoring is not being done.

- **For each WWTP, please fill in Table 4 to the best extent possible. Please see Annex 2 for a glossary of wastewater terminology. Please copy and paste this table as needed if more than one treatment plant exists within the study site:**

Table 4: Wastewater Treatment Plant information for current situation

Data need	Data
Design	
Location	Bocas Town
Design capacity - Nominal design capacity for dry and wet weather flows.	3,055 m^3/day (PURITEC-GES)
Treatment technology (e.g., waste stabilization pond; oxidation lagoon)	Aeration lagoons
Effluent limits	
Sludge treatment and disposal	
Discharge location (receiving water body). If coastal, identify the outfall locations.	

Ease of operation (description of the no. of staff needed to operate; the technical complexity of operation; and overall ease of operating and maintaining the infrastructure)	
Performance	
Current flows (annual average flow, monthly average peak flow)	
Annual energy usage (kW hours, total cost)	
Occurrence of bypassing at the treatment plant for the period 2010-2014 due to high flows, equipment failures, or power outages (list date, cause and estimated bypassed volume for each event).	
Occurrence of overflows in the collection system due to heavy rain, equipment failures, or blockages (average per year)	Reported over flow occurrences during period of very heavy rainfall
Annual average discharged concentrations and loads of:	Not available
• BOD_5 (mg/l, kilograms per year)	
• Dissolved oxygen (mg/l)	
• Total Nitrogen (mg/l, kilograms per year)	
• Ammonia Nitrogen (mg/l, kilograms per year)	
• Total Phosphorus (mg/l, kilograms per year)	
• Total Suspended Solids (mg/l, kilograms per year)	
• Faecal coliforms (units as reported)	
• Enterococci (units as reported)	

5. What is the estimated annual percentage of total wastewater generated that is <u>untreated</u> and released into water bodies? What is the estimated annual volume?

Not sure, but there is definitely some untreated wastewater that is being released directly into water bodies. According to the Management Plan for Bocas del Toro (CONADES 2008a), the concentrations of

organic material and nutrients in the coastal waters are reducing the level of dissolved oxygen and stimulating the growth of algae, i.e. eutrophication. This is creating environmental health problems and is aesthetically displeasing to tourists in sites of high tourist population density.

6. **If there is untreated sewage, where does this go? If possible, please also note on a map the receiving water bodies and ecosystems that receive the untreated sewage – either directly, or via an outfall.**

Untreated sewage is known to pass directly into the mangroves and coastal waters (CONADES 2008b).

7. **Is there an interest in improving, upgrading, or expanding the current wastewater management system in the area? If so, please describe who is interested and why.**

Yes. A new inter-institutional committee has been established to deal with water issues in Isla Colon, including wastewater, a desalinization plant, the indigenous settlements, and other topics. The Committee includes the Ministry of Environment, the Ministry of Health, IDAAN, and CONADES.

Additionally, as part of the 100/0 plan, the government of Panama (through CONADES) is currently working on a census to identify wastewater infrastructure conditions in the. The census is a household survey to identify current WW treatment efforts by all residences, commercial establishments, etc. The census must first be completed before any selection of future infrastructure is made.

8. **Current wastewater treatment costs - What capital and annual operating and maintenance costs are associated with the current wastewater management situation? Please fill in Table 5 to the best extent possible. If you do not have specific cost data, please provide a description of the *likely* costs associated with the current scenario by referring to Annex 2, section D.**

Table 5: Current wastewater scenario costs

Data need	Current wastewater management situation
Year of installation	2010 (for aeration system)
Life expectancy (years)	unknown
Total land area occupied by the plant (hectares)	
Recurring capital expenses (e.g., please list which infrastructure components will need to be replaced within the next 20 years and the total capital cost, including likely year of replacement and the frequency of replacement)	The initial investment cost for the plant has been estimated at $2.2 million dollars for a demand of 11,000 people (MdA 2015a). It is not clear what the recurring capital expenses are, however.
Annual recurring expenses:	$8000/month (MdA and WRI 2015)

-Salary/wages for all personnel plus personnel of any contracts associated with operation of the WWTP. -Operational and maintenance costs (e.g., chemicals, consumables, maintenance, etc.) -Energy costs (annual energy costs only for the operation of the selected project)	
External services costs (if applicable, net value of total costs of external services including outsourcing, costs for construction)	
Discount rate (please list the discount rate(s) typically used by the wastewater management authority for infrastructure projects)	
Other costs?	
Net present value over infrastructure's lifetime	

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VI. WATER QUALITY

Objective: To identify and list water quality standards and requirements that are applicable to the wastewater sector and identify and provide historic data (over the past five years) on water quality within wastewater receiving bodies and key ecosystems in the study area.

Possible data sources: Environmental/water/natural resources agencies or ministries; Wastewater authorities; Consultants or engineers that work with the wastewater authority

1. What water quality standards/requirements apply for the study area?

- **National/Regional and Local water quality standards?**
  - **Designated uses (e.g., bathing/swimming) or water body classification (e.g. fisheries, recreation)**
  - **Numeric criteria?**

- **Bathing/swimming standards**

- **International standards (e.g., LBS Protocol)**

- **Designated uses (e.g., bathing/swimming) or water body classification (e.g. fisheries, recreation)**
- **Numeric criteria?**

The relevant wastewater standards for Panama include the LBS Protocol[2] (of which Panama is a signatory) and the national Technical Regulation DGNTI-COPANIT 35-2000: Water Effluent discharges directly into bodies of surface water and groundwater (see Table 1).

Table 1: Wastewater quality standards for Panama

POLLUTANT TYPE	Land Based Source Protocol Standard	Panama Coastal Water Body Standard (DGNTI-COPANIT 35-2000)
Five Day Biological Oxygen Demand (BOD_5)	30 mg/l	35 mg/l
Total Suspended Solids	30 mg/l∗	35 mg/l
Faecal Coliforms (Freshwater)	200 MPN/100 ml;	N/A
Faecal Streptococci	N/A	N/A
Enterococci (Saline water)	35 organisms/100 ml	
Total Phosphorus	"take appropriate measures to control"	5 mg/l
Total Nitrogen	"take appropriate measures to control"	6.0 mg/l NO_3 10.0 mg/l N
Solid Waste	N/A	N/A
Fats, Oil and Grease	15 mg/l	20 mg/l

[2] The LBS Protocol is a regional mechanism assisting the United Nations Member States in the Wider Caribbean Region to meet the goals and obligations of two international agreements: The United Nations Convention on the Law of the Sea (UNCLOS) and the Global Plan of Action for the Protection of the Marine Environment from Land-Based Activities (GPA). UNCLOS calls upon States to adopt laws and regulations to prevent, reduce and control pollution of the marine environment from land-based sources

∗ Does not include algae from treatment ponds

Under the technical regulation DGNTI- COPANIT 35-2000 (which regulates the discharge of liquid effluents), constructors were obliged to develop their housing projects with water treatment plants instead of connecting them to septic tanks. Legally, IDAAN is responsible for collecting and accepting treatment plans for all buildings constructed by developers or individuals. While, IDAAN has financial and operational limitations, they have assumed the cost of operating and maintaining all sanitary facilities.

2. What data or information do you have about water quality in the study area? Can you provide:

- **Ambient water quality monitoring data in freshwater bodies?**
- **Ambient water quality monitoring data in coastal waters?**

Stakeholders at the MdA and WRI workshops (2014, 2015) stated that water quality data is not collected currently. There is a lot of confusion from applicable Ministries on who is responsible for what. The general understanding, however, is that:

- IDAAN should monitor water quality at wastewater discharge points
- The Autoridad de Recursos Acuáticos de Panamá (ARAP) should monitor water quality after an environmental event (e.g., fish kill)
- MdA should monitor water quality of fresh water bodies

IDAAN does not have any water quality data available for Isla Colon.

3. Please compare these data to water quality standards/requirements:

- **Are any water quality standards being violated in lakes, non-tidal streams and rivers, and coastal areas? Please provide frequency and severity.**
- **What are the pollutants causing the violation and what are their sources (e.g., untreated wastewater, WWTP effluent, onsite septic systems, soakaways, pit latrines, sources from other sectors such as mining or agriculture)**

Data not available.

4. If any water quality standards are being violated, have the violations been linked to wastewater discharges? If so, please provide specific information on the linkage.

Data not available.

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VII. ECOSYSTEM IMPACTS

Objective: To understand if there is a demonstrated link between wastewater pollution and ecosystem health.

Possible data sources: Environmental/water/natural resources agencies or ministries; Wastewater authorities; Consultants/engineers working with the wastewater authority; Environmental impact statements; Environmental/marine NGOs and government agencies; Academic and grey literature.

1. **Within the study area, are any of the following causing ecological impacts, such as algal blooms or damage to coral reefs:**
   - **Discharge of untreated or partially treated sewage?**
   - **Discharge of treated wastewater effluent?**
   - **Irregular release of wastewater from a WWT system due to overflow, rainwater events, or power failure, etc.?**

Stakeholders from the MdA and WRI workshops (2014, 2015) state that discharge of untreated domestic wastewater and irregular release of wastewater from the WWTP is likely impacting ecosystems, although not to an extent that is yet impacting tourism or livelihoods.

The 2008 Management Plan (CONADES 2008a) says that microbiological levels (i.e., fecal and total coliforms) should be being measured every three months, as these have the greatest potential to impact human health. However, there is no evidence that any of these contaminating substances have been measured or that there are limits for their amounts.

Degradation of coral reef communities due to an increase in anthropogenic impacts has been documented in reefs across the Caribbean, and within Almirante Bay (Bahía Almirante) in Bocas del Toro, Panama (Guzmán and García 2002; Collin 2005; Guzmán et al. 2005; Collin et al. 2009; Karpenter et al. 2008; Seenmann et al. 2014). It is not clear, however, the extent to which untreated wastewater is contributing to this degradation.

In 1999 the Smithsonian set up coral reef monitoring systems at their field station on the Isla Colon and as of 2008, had 33 different testing sites up and running. However, to date, no studies have specifically linked wastewater pollution to ecosystem health in this area.

We found several other studies that have looked at ecosystem impacts near Isla Colon, however, none mention domestic wastewater as a pollution source. Seemann et al. (2014) conducted a study assessing the ecological impacts of human impacts on coral reefs in Bocas del Toro. They conducted environmental and biological reef monitoring in Almirante Bay (Bahía Almirante) that assessed how seasonal temperature stress, turbidity, eutrophication and physical impacts threatened reef health and biodiversity throughout the region. Environmental parameters such as total suspended solids [TSS], carbon isotopes (δ13C), C/N ratios, chlorophyll a, irradiance, secchi depth, size fractions of the sediments and isotope composition of dissolved inorganic carbon [DIC] of the water were measured

throughout the years 2010 and 2011 and were analyzed in order to identify different impact sources. The study found:

- Eutrophication and turbidity levels seemed to be the determining factor for the loss of hard coral diversity, most significant at chlorophyll a levels higher than 0.5 µg l−1 and TSS levels higher than 4.7 mg l−1. Hard coral cover within the bay has also declined, at some sites down to <10 % with extremely low diversities (7 hard coral species). The hard coral species Porites furcate dominated the reefs in highly impacted areas and showed a strong recovery after bleaching and a higher tolerance to turbidity and eutrophication compared to other hard coral species in the bay. Serious overfishing was detected in the region by a lack of adult and carnivorous fish species, such as grunts, snappers and groupers. Study sites less impacted by anthropogenic activities and/or those with local protection showed a higher hard coral cover and fish abundance; however, an overall loss of hard coral diversity was observed.
- Also, hard coral species richness has declined from 60 species reported for the Caribbean and 58 species reported for the Bocas del Toro area to 42 species
- The authors did not discuss wastewater as one of the anthropogenic impacts, however, but did link nutrients from fertilizers as well as coastal developments.

Berry et al. (2013) found that anthropogenic activities have a negative impact on coral tissues and sediments in Bocas del Toro due to heavy metals. Sources of heavy metals were cited as shipping activities from the Port of Almirante, *domestic sewage*, agricultural activities and unpredictable sources such as oil waste by tankers.

Cramer et al. (2012) found evidence of increasing environmental stress on reefs in Bocas del Toro, namely reductions in bivalve size and simplification of gastropod trophic structure. The authors list possible causes of environmental stress as: land clearing, initially for banana production but then for tourism; and fishing.

2. Have any studies been conducted within the study site or your country or region that link wastewater pollution to ecosystem health? If so, what are the findings?

In Panama, new developments and infrastructure (like WWTPs) should complete an Environmental Impact Study (EIS). IDAAN (2015) states they have completed an EIS for the aeration system in Isla Colon from 2013 but they were not able to provide it at this time.

3. Is there evidence of the following in any of the key ecosystems present in the study area: (e.g., freshwater, wetlands, mangroves, beaches, coral reefs, forests, wetlands):

- **Is it unsightly due to pollution? Are there algal blooms or obvious evidence of pollution?**

Stakeholders from the MdA and WRI workshop (2014) said they are not noticing any algal blooms.

- **Is there odor due to pollution?**

There are reports of odor in coastal mangroves (MdA and WRI workshop 2014).

- **Are there impacts to fish or other aquatic life (e.g., fish kills, overgrowth of algae on coral reefs)?**

Not sure.

- **Are you seeing a change in ecosystem health and/or growth?**

Recent water quality monitoring data from the Smithsonian Tropical Research Institute (STRI) has shown that despite the continued deforestation on the mainland and development in the islands, water quality has not shown any significant decrease over the last 10 years. However, STRI notes that clarity and chlorophyll concentration hover near the levels indicative of eutrophication (STRI 2008).

However, stakeholders at the MdA and WRI workshop in 2015 stated that they are seeing a decrease in the starfish population at Starfish beach and that mangroves around the WWTP are being negatively impacted.

4. **Beyond wastewater, are there any other sources of water pollution contributing to these problems? If so, please indicate the relative contribution to total water pollution using the following scale:**

   No contribution – Minor contribution – Moderate contribution – Significant contribution

   - **Runoff from croplands?**
   - **Runoff from livestock?**
   - **Runoff from aquaculture?**
   - **Industrial discharge?**
   - **Cruise ships/yachts?**
   - **Others?**
   - **Do you have a sense of the relative contribution from wastewater to overall pollution of key ecosystems compared to these other sources? If so, please describe.**

Yes, evidence from the studies above show that agricultural runoff, port activities, and coastal development and land clearing are contributing to pollution. It is unclear the percentage of total contribution however from each pollution source. These environmental stressors may cloud what we know about untreated wastewater effluent pollution entering coastal areas.

5. **Are there any economic or cultural uses of the key ecosystems that are in decline due to wastewater discharge issues (from untreated or improperly treated wastewater)? Please refer to Annex 2, section B for examples of Caribbean coastal ecosystems and impacts that have been documented from exposure to untreated or improperly treated wastewater.**

Not sure.

6. **Do tourists have any awareness of water quality issues and do they modify activities / visitation? Are you able to quantify or describe the change in visitation (e.g., reduced annual snorkeling rates or reduced number of visitors to recreational beaches)?**

Stakeholders at the 2014 MdA and WRI workshop state that tourism has not yet been impacted from pollution and changes in ecosystem quality; however a recent water quality problem in May 2015 caused by contamination of Big Creek water which led to a fish die off which was cause for high alerts for tourists. The issue was temporary and water quality was approved for human consumption within a few days, but a prolonged water quality issue like this could have a profound impact on the desirability of tourists to visit the area. In a single day over 9 thousand gallons of water were delivered to the island, luckily the water was tested and found to be suitable for human consumption before it negatively impacted the tourism industry. While the cause of the fish kill in Big Creek Lake in this instance was a lack of maintenance causing over-sedimentation, the introduction of non-local Tilapia fish and not wastewater (according to MOE), the high alert that went out to tourists is indicative of the impact that wastewater contamination could have on tourism in the area if it contaminated the drinking water or became a health concern.

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VIII. HUMAN HEALTH IMPACTS

Objective: To understand if there is a link between wastewater pollution and key human health illnesses including gastroenteritis, ear and eye infections, and other illnesses (as listed in Annex 2, section C); and to estimate the impacts on the local economy due to human health impacts (e.g., from hospitalization, medication, time taken off work, and death).

Possible data sources: Health agencies or ministries; Hospitals or doctor's offices; national statistics/census data; international statistics from multilateral, intergovernmental or NGOs (e.g., World Bank or World Health Organization); peer-reviewed or grey-literature.

1. **Please describe any known human health impacts, such as gastrointestinal illness, respiratory illness, ear infections, eye infections, or skin rashes/lesions that are occurring in the study site that relate to wastewater. Please see Annex 2, section C for a list of human illnesses related to swimming in, drinking from, or eating seafood from water contaminated with wastewater.**
    - **Are health data recorded on any of these key illnesses? If so, who collects this data? What can you say about the average frequency and duration of occurrence for each type of illness (e.g., 50 cases per year; 1 case per resident person per year)?**
    - **Do reported incidences of these illnesses result in doctors' visits, hospitalization, or death? Do you have statistical data on illnesses and hospital data?**

- **What activities seem to be contributing (e.g., swimming; eating contaminated seafood)?**
- **How specific can you be about location?**
- **Is wastewater pollution the main cause of these health issues? If not, what are the main causes of these diseases?**

There are local concerns that the indigenous population may be impacted by untreated wastewater as they live adjacent to the plant and in the mangroves that receive untreated wastewater. Stakeholders from the 2014 MdA and WRI workshop stated there may be a higher infant mortality rate with the indigenous population partially due to exposure to wastewater pollution

Silva (2015) provides information on health issues related to improper sanitation. Harmful algal blooms also impact fish species, many of which are consumed by people. While the report does not list Isla Colon as an area impacted by Red Tide events (harmful algal bloom events), the following Table below shows outbreak case numbers for illnesses related to consuming contaminated seafood in Panama:

Reported Cases of Hydroalimentry (Water-Food) Related Disease in Panamá, classified by type, 2003-2007							
Year		**Total**	**Amebasis**	**Diarrhea**	**Food Poisoning**	**Salmonella**	**Shigellosis**
2003	Cases	191,729	5,542	184,529	1,073	74	61
	Rates[a]	6,138.10	177.8	5,921.50	34.4	2.4	2
2004	Cases	174,667	4,953	168,374	1,246	54	40
	Rates	5,506.90	156.1	5,307.50	39.3	1.7	1.3
2005	Cases	173,908	4,953	167,130	1,179	59	89
	Rates	5,387.20	156.1	5,177.20	36.5	1.8	2.8
2006	Cases	205,389	5,451	198,428	1,246	105	62
	Rates	6,254.30	168.9	6,042.30	37.9	3.2	1.9
2007	Cases	193,309	5,268	186,760	1,179	76	26
	Rates	5,788.10	157.7	5,592.00	35.3	2.3	0.8

The following information for Panama is taken directly from Silva (2015): "In 2007, 193,309 cases of hidroalimentary illness were reported, with diarrhea holding the highest number of cases (198.428), followed by amebiasis (5,268) and food poisoning (1.179) (Table 26). Diarrhea showed an upward trend, with more than one million cumulative cases, an average 112,287 and a monthly average of 9,357 cases during 1995-2003. Reportedly, in 2003, a national rate of 6,075 cases per 100,000 inhabitants, and the Bocas del Toro region with the highest incidence rate (from 9343 to 11449 cases per 100,000

population) followed by Chiriquí, the Metropolitan region and San Miguelito, located rates range from 7236.9 to 9343 cases per 100,000 inhabitants. Children under 5 years are the most affected by diarrheal diseases. Within this group, children under one year have between 1.5 and 2.0 times the risk of disease among children under five years and between 1.7 and 2.5 times the risk that the group of 1-4 years. By 2003, the incidence rate of diarrheal diseases in children under five years was 4 times higher than the general rate in the country; 6 times greater for patients younger than 1 year and 3.4 times higher for the 1-4 years. Acute diarrheal diseases show a seasonal pattern with higher frequencies in the rainy season.

The indigenous regions present the major causes of morbidity and mortality due to digestive diseases related to unsafe water intake and poor disposal of excreta; so the incidence of diseases like diarrhea is high (Table 27). Among the population under 5 years, the frequency of diarrhea has seen a steady increase from 24,391 in 1987 to 16,046 per 100,000 inhabitants (2006), at the expense 1-4 years group, where occurrence has doubled from 11,606 to 21,828 per 100,000 individuals.

Mortality Rates and Statistics of Gastrointestinal Disease for Nogbe Bugle, Guna Yala and the Province of Darién Counties, 2009

Principle Indicators	Nogbe Bugle	Guna Yala	Prov. of Darién	Republic of Panamá
General Rate of Mortality per 1,000 hab.	3.51	6.8	2.7	3.9
Rate of Infant Mortality per 1,000 hab. Of Live Births	19.15	22.3	22.6	11.9
Mortality in Children Linked to Poor Water Quality (ages 0-4)				
Diarrhea and Gastroenteritis of Presumed Infectious Origin	4,825	2005	3,122	-
Intestinal Parasitosis, Without Other Origin	5,011	-	-	-
Morbidity in Children Disease Linked to Poor Water Quality (20-59 years)				
Diarrhea and Gastroenteritis of Presumed Infectious Origin	-	486	1,571	-
Intestinal Parasitosis, Without Other Origin	2,505	-	-	-
Morbidity in children linked to poor water quality (over 60 years) diseases				
Diarrhea and Gastroenteritis of Presumed Infectious Origin	-	197	-	-
Intestinal Parasitosis, Without Other Origin	456	-	349	-

Despite government efforts through implementation of health programs, the Ngäbe-Buglé[3] have high rates of infant mortality. Diseases and most common causes of death are tuberculosis, intestinal infections, diarrhea, whooping cough, infectious and parasitic diseases and malnutrition. There are very few jobs or health sub-centers in the region. Those that exist have sparse coverage, infrastructure equipment and supplies and do not have equipment, medicines and sufficiently trained health personnel. Some of the morbidity and mortality in these regions is related to poor hygiene and diseases that can be treated with prior medical care (vaccination).

According to WHO, the environmental burden of disease Panama is 200 deaths related to water and sanitation; the Years of Life Lost due to Disability (DALYs for its acronym in English) is 9600. The burden of environmental disease is 25/1000, which equates to 80,000 DALYs. (World Health Organization 2015).

The report also states that the conditions of basic sanitation contribute to both the transmission of both dengue and malaria. Bocas del Toro has one of the highest rates for both illnesses. In the past, the habitat of the Aedes Aegypti Mosquito, which transmits dengue, was considered to be clean and stagnant waters. However, studies in Puerto Rico and Peru by the CDC have reported the discovery that mosquitoes carrying dengue may also have farms in septic tanks and sewage systems. As for malaria, the high levels of nitrogen and phosphorus cause eutrophication problems in those bodies of water flowing slowly. Increased levels of nitrogen and phosphorus associated with untreated wastewater might lead to increased risk of malaria in Isla Colon, which could impact the local community as well as the tourism industry.

2. Have any studies been conducted within the study site or your country or region that link wastewater pollution to human health?

Yes – Silva (2015) for Panama. No studies have specifically been conducted for Isla Colon.

3. Do any of these studies estimate a dose-response relationship between a given wastewater pollutant and a human health illness (e.g., gastroenteritis)? (See the BCA methods section for more detail.)

No.

4. Beyond wastewater, are there any other sources of water pollution contributing to these problems? (If so, please note how large of a contribution.)

- **Runoff from agriculture?**
- **Runoff from livestock?**
- **Runoff from aquaculture?**

[3] The Ngäbe-Buglé are a local indigenous population in Panama.

- **Industrial discharge?**
- **Cruise ships/yachts?**
- **Others?**

Not sure.

5. **Do you have a sense of the relative contribution from wastewater to overall health impacts compared to these other sources? If so, please describe.**

No – no health data were available or provided by the county medical office and no site-specific dose-response relationships are available for wastewater pollutants.

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IX. FUTURE WASTEWATER MANAGEMENT SCENARIO(S)

Objective: To identify and define at least one future wastewater management scenario to compare against the current infrastructure situation in terms of population served, untreated wastewater, pollution removal efficiency for key pollutants, and capital and recurring costs.

Possible data sources: Wastewater authorities; Wastewater consultants or engineers that work with the wastewater authority; Environmental/water/natural resource agencies or ministries that issue wastewater permits.

1. **What option or options are under consideration for improving wastewater management in the pilot area? Please provide a description and fill in Table 6 for each major wastewater treatment plant or infrastructure element. Please add columns as necessary if more than two alternatives are being considered.**[4]

As of August, 2015, IDAAN and CONADES are currently considering a few options for improving wastewater management in the Isla Colon area, under the Inter-Institutional Committee. IDAAN and CONADES appear to be considering two options for medium to long-term wastewater treatment (IDAAN 2015):

- Extension of the sewer system in Isla Colon to connect Isla Carenero to the Isla Colon WWTP. Would include conversion of the current dormant lagoon into a dry lagoon for sludge disposal.

[4] Note – since August 12, 2015, the understanding of the future wastewater management options for Isla Colon has changed. The Ministry of Environment states that the new understanding of future plans for wastewater treatment in Isla Colon is that the current WWTP in Bocas Town will be decommissioned and a new plant will be constructed. Additionally, the sewerage network will be extended to cover the entire population of the island. Not included in the scenario, but relevant for understanding ecosystem and health impacts for the island, is that a new WWTP will also be constructed for the neighboring island of Isla Carenero. Additionally, the sewerage network will be extend on that island. The total estimated costs for both islands is 15.5 million dollars.

- Extension of the sewer system to connect Isla Carenero to the Isla Colon WWTP AND expand the current WWTP by converting the dormant lagoon into a second oxidation lagoon with aeration system.

Table 6: Future wastewater management scenarios description

Data need	Alternative 1	Alternative 2
Design		
Location		
Design capacity - annual average and peak (if actual capacity is lower, that will be covered below under performance)		
Treatment technology (e.g., waste stabilization pond; oxidation lagoon)	Oxidation pond with aeration system (1 pond)	Oxidation pond with aeration system (2 ponds)
Will effluent and water quality standards be met?	Yes	Yes
Sludge treatment and disposal	At dormant lagoon adjacent to current oxidation pond	
Discharge location (receiving water body). If coastal, is there an outfall(s)?		
Ease of operation (description of the no. of staff needed to operate; the technical complexity of operation; and overall ease of operating and maintaining the infrastructure)		
Performance		
Flows (annual average, peak)		
Annual energy usage (kW hours, total cost)		
Occurrence of bypassing at the treatment plant for the period 2010-2014 due to high flows, equipment failures, or power outages (list date,		

cause and estimated bypassed volume for each event).		
Occurrence of overflows in the collection system due to heavy rain, equipment failures, or blockages (average per year)		
Annual average discharged concentrations and loads of:		
• BOD_5 (mg/l, kilograms per year)		
• Dissolved oxygen (mg/l)		
• Total Nitrogen (mg/l, kilograms per year)		
• Ammonia Nitrogen (mg/l, kilograms per year)		
• Total Phosphorus (mg/l, kilograms per year)		
• Total Suspended Solids (mg/l, kilograms per year)		
• Faecal coliforms (units as reported)		
• Enterococci (units as reported)		

2. **What are the evaluation criteria for choosing an infrastructure option and who decides what these criteria are? For example, criteria may include cost-effectiveness, pollutant removal efficiency, and/or environmental impacts.**

The option will be selected by the inter-institutional committee, but it is not clear how the committee will select the option.

3. **What sort of improvements are expected from each future wastewater management scenario?**
   - **Increased coverage in terms of population treated?**
   - **Improvement in water quality of receiving water bodies and downstream water bodies?**
   - **Reduced levels of:**
     - **BOD5**
     - **Dissolved oxygen**

- **Total nitrogen**
- **Ammonia nitrogen**
- **Total phosphorus**
- **Total suspended solids**
- **Faecal coliforms**
- **Enterococci**

Data not available.

4. Will the new wastewater treatment technology allow any reuse of water?

- **Where does the treated water go – back in a river, out an outfall, or into a specific use (e.g. irrigation, industrial use, or drinking water)?**
- **Has anyone estimated the potential cost savings associated with reuse of this wastewater?**

No.

5. Have any engineering or financial analyses been conducted for future wastewater management alternatives? Do they provide cost data?

We were not able to find specific engineering or financial analysis conducted on future wastewater management alternative scenarios, however, IDAAN and CONADES have developed a budget estimate for future upgrades for the inter-institutional committee. CONADES (2015) has estimated a cost of $12,000,000 for the following activities:

- Conduct necessary studies and designs for the construction of the WWTP in Isla Colon.
- Study, design and construct the outfall for wastewater to the WWTP Carenero island Isla Colon.
- Extend the sewer system of Isla Colon.
- Optimize the existing sewerage system Isla Colon.
- Construct sanitary units for areas that are not served by sewers.
- Conduct an environmental impact study.

It is not clear if this cost applies to future option 1 vs future option 2, but can be used as a proxy for the costs for items listed above.

6. Please fill in Table 7 to the best extent possible based on either engineering/financial reports from the wastewater authority and relevant consultants, OR by referring to Annex 2 which provides information on relative cost by infrastructure type.

Table 7: Cost estimates for future wastewater management scenarios

Parameter	Alternative 1	Alternative 2

Year of installation		
Life expectancy (years)		
Total area of the plant (please list the area that will need to be purchased for the treatment facility)		
Capital/Investment expenses (This includes one-time construction, planning, and design costs, costs for new development, and cost for replacement and renovation of existing assets – including external or consulting services)		
Recurring capital expenses (e.g., please list which infrastructure components will need to be replaced sooner than the life expectancy of the treatment facility and the recurring capital cost, including likely year of replacement and the frequency of replacement)		
Annual recurring expenses: -Salary/wages for all personnel -Land rental value for land purchased (i.e., the value of land purchased to install the wastewater infrastructure) -Operational and maintenance costs (e.g., chemicals, consumables, maintenance, etc.) -Energy costs (annual energy costs only for the operation of the selected project)		
Discount rate (please list the discount rate(s) typically used by the wastewater management authority for infrastructure projects)		
Other costs		
Net present value over infrastructure's lifetime		

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X. CHANGES TO ECOSYSTEM AND HUMAN HEALTH UNDER IMPROVED WASTEWATER MANAGEMENT SCENARIOS

Objectives: To quantify and/or describe how ecosystems and the goods and services they provide will change under each future wastewater management scenario, and the potential impacts on the local economy in terms of costs;

To quantify and/or describe how human health will be impacted under each future wastewater management scenario in terms of numbers of reported illnesses and costs.

Possible data sources: Peer-reviewed and grey literature; Government documents including environmental impact statements.

1. **Have any evaluations, studies, or environmental impact statements been conducted that estimate the impact on key ecosystems and human health under each new wastewater management scenario *compared to the current wastewater management situation*? Do you know of any experts that are currently studying potential impacts? If so, please describe these findings, including how likely management under each scenario is to:**
   - Reduce the annual loading of pollutants on receiving water bodies?
   - Reduce odor?
   - Reduce the incidence of harmful algal blooms and/or nutrient over-enrichment?
   - Reduce human health risk and/or the number of cases for illnesses previously identified?
   - Improve ecosystem health conditions for the key ecosystems identified previously?
   - Improve the provision of key ecosystem goods and services identified previously (e.g., increased likelihood of tourist visits, increased productivity of fisheries due to improved coral reef and mangrove health)

No – no environmental impact studies have yet been conducted.

2. **Can you establish a quantitative relationship between an improvement in water quality due to the future wastewater management alternative and a change in provision of ecosystem services for each key ecosystem? If so, please list your assumptions and quantitatively describe these changes (e.g., by reducing the amount of untreated wastewater entering the coral reef ecosystem, total nitrogen levels will decrease by 30% surrounding the reef which will improve coral reef health such that fisheries production increased by 20%).**

No.

3. Can you monetize or value the change in ecosystem service provision (e.g., what is the economic value of reduced coral reef degradation in terms of fisheries improvement – this is often quantified by estimating the market value of fish sold in a marketplace)?

No.

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XI. OTHER INFORMATION

1. Please list any additional data or information you think would be useful to the study that might not have been discussed previously in this characterization form.

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