Baseline Report Wastewater Demand/Market Analysis Financial and Economic Model

November 2021

Revision Final

Contents

List of Tables

List of Figures

1. Introduction

The overall purpose of the consultancy as set out in the Terms of Reference is:

“to assist the Barbados Water Authority (BWA) to deliver a financial and economic analysis (FEA) for the recommended project in compliance with the GCF and Barbados’ requirements, including a financial and economic summary of works to be conducted under the project.”

With specific objectives being:

1. To provide the Government of Barbados through the BWA, the CCCCC and GCF with sufficient financial and economic information to justify acceptance, modification or rejection of a proposed list of financially ranked wastewater treatment project interventions with a climate change adaptation dimension. The list would include priority components within the projects, which would support the implementation of the proposed objectives of the Project ‘Building Resilience of wastewater management to climate change in Barbados’,
2. To provide the Government of Barbados through the BWA, the CCCCC and GCF with guidance in the selection process of the most suitable and relevant projects for further project formulation, based on the amount of funds available under the GCF, in support to the implementation of the Project ‘Building Resilience of wastewater management to climate change in Barbados’,
3. To provide the related documentation for selected projects prepared for submission to the BWA and for consideration for financing.

The Terms of Reference set out three Tasks and four Deliverables to be achieved. These are 1) The Inception Report, 2) The Baseline Study and Wastewater Demand/Market Analysis Financial and Economic Model, 3) A Financial and Economic Analysis Report and Action Plan including Non-Technical Summary (NTS) for disclosure to the public, and 4) A Stakeholder Engagement Report.

The Inception Report set out the proposed methodology for conducting the consultancy work and the assumptions on which it is based. The methodology broadly followed the Terms of Reference and the Tasks set out therein. The 3 Tasks identified were:

Task 1: Baseline Study and Wastewater Demand/Market Analysis,

Task 2: Develop a Financial and Economic Model,

Task 3: Conduct a Financial and Economic Analysis and Action Plan.

This Baseline Study Report sets out the work undertaken under Task 1 and provides the basis for the development of Task 2 and the assumptions informing not only the development of the model but also the parameters to be used in the model.

The information used in this report has been gathered from information requests to the Barbados Water Authority, the Ministry of Agriculture and Food Security, the Barbados Agriculture Development Corporation and the Barbados Statistical Service. In addition, information on costs associated with the design and operation of the Bridgetown and South Coast Sewage Treatment Plants has been taken from the AECOM (2020) South Coast Water Reclamation Pre-Feasibility Study, and from the following reports produced by Integrated Sustainability; Baseline Study (2021), Conceptual Design (2021), and Feasibility Study (2021). The recommendations from these reports, particularly the Feasibility Study (2021) have been incorporated into this report.

2. Economic Background

2.1 Current conditions

2.1.1 Population

Barbados is classed by the World Bank as a high-income country, with an economy that has transitioned from being agriculturally based in the mid-twentieth century to one based predominantly on coastal tourism and financial services. The effect of this has been to concentrate the population and supporting services along the coastal areas leading to a densely urbanised band of development that runs down the west coast through the Bridgetown area, with its port and government services, and along the south coast, leaving only the east coast relatively undeveloped. The population of Barbados is estimated to be 287,000 (World Bank, 2021) and this is projected to peak in 2031 after which it is projected to decline. The workforce in 2019, before the impact of Covid-19 was estimated at 155,400 or 54% of the total population. The overall dependency ratio was 50.3%, implying that one person in the workforce supports one person who is either below the age of 15 or above the age of 65. The urban population constitutes 31% of the population, down from 40% in 1980, reflecting a trend of increasing peri-urban development outside of the historic core urban areas such as Bridgetown. In September 2020, the Governor-General in opening a new session of Parliament indicated that the Government planned to tackle the declining birth rate and address the human resource deficit of 80,000 persons through immigration reform. A figure of adding an additional 100,000 persons has apparently been mentioned but no details as to how this is to be achieved have been made public.

2.1.2 Economic performance

In 2010 the percentage of the population that was living in poverty was 15.1% and in 2016 this had increased to 17.2% according to the Barbados Survey of Living Conditions. It is thought likely that this figure has increased, in line with the economic slowdown experienced since then. In fact, since the global financial crisis of 2008, Barbados has experienced low and negative real economic growth. Inflation rates have been around 4% per year over the last 4 years and is projected to remain at around 3% per year in the medium term. A combination of economic circumstances and poor management of the economy led to a situation where public debt increased consistently from 55% of GDP in 2008 to 158% in 2017, leading to a further slowing down of the economy. As a result, in June 2018, the new administration announced the Barbados Economic Recovery and Transformation (BERT) Programme to reduce expenditure and raise revenues. Including a more aggressive approach to reducing expenditure on State Owned Enterprises (SOEs). Part of this entails the reduction in the number of parastatal bodies and a reduction in subsidies to those remaining – though the pandemic has hampered this process. The BERT Programme included the suspension of debt payments and a comprehensive restructuring of domestic and external debt, completed in 2019. Under BERT debt is targeted to drop to 60% of GDP by 2034. At the same time, the Government, in 2018, entered an adjustment program under the IMF’s Extended Fund Facility.

2.1.3 Covid-19 Impacts and Responses

The Covid-19 pandemic has had a major impact on the economy in several ways. Tourist arrivals dropped dramatically affecting tourism, retail, and business activities. Hotel occupancy rates were below 50 %, with a steep decrease in revenues. The tourism sector is estimated to contribute 25% of national employment but with the virtual closure of the sector hotels and related businesses have closed which has led to increased unemployment and increases in benefit claims (CDB, 2020). As a result the economy contracted by 18% in 2020 (World Bank, 2021) with severe job losses, particularly among the vulnerable population. In June 2020 a rapid assessment survey estimated that almost half of respondents that were employed before the pandemic reported losing their job (IDB, 2020). This has affected low-income households more severely than middle and high-income households. Similarly, women have been more impacted than men.

Unsurprisingly the management of the Covid-19 pandemic has placed strain on the economy which must be carefully managed given the fiscal and debt targets under BERT. The CDB commented (CDB, 2020) that "*efforts to drive growth will depend partly on the private sector and their confidence about a timely recovery. The Government will need to accelerate its structural reforms, including improving the business climate and fostering economic diversification. Strengthening resilience to natural disasters and climate change will also be key to long-term economic growth."* The short-term outlook (up to 3 years) according to both the World Bank and CDB is reasonably positive. Both project a modest economic recovery, contingent on the recovery of the tourism sector and a resumption of Foreign Direct Investment (FDI).

Short-term measures have included expanding social assistance and implementing a program that subsidizes continued employment in the tourism sector. At the same time the Government has sought to boost expenditures on capital projects and stimulate construction activity, including in the tourism sector. There is still an expectation that tourism will form a major part of economic activity in the medium term. And on the back of tourism, it expects that construction activity will keep pace, announcing in March 2021 several major private sector investments in and around Bridgetown.

At the same time, the Government is looking to expand the agricultural sector through support measures to increase food production and substitute for imports. One of the side effects of the pandemic, coupled with the economic downturn that had preceded it, has been an increase in small-scale subsistence farming – a move that the government is seeking to support through its FEED programme. However, despite the good intentions, the agricultural sector faces significant constraints in the areas of basic information, availability of land, availability of finance, extension services, the ability to attract young persons into the sector, a lack of entrepreneurial activity and poorly developed agro-processing and marketing opportunities. There is also interest in seeking to develop a Blue Economy, but plans are in their infancy and it is likely that it will be at least 10 years before any significant activity in this sector is registered.

Given the structure of the Barbados economy, it is likely that a large section of the working population is going to continue to be employed either in government or the services sector. Furthermore, a large percentage of the current population has only basic qualifications. Women's' participation rate in the economy is relatively high at around 60%, compared to the male participation of 68%, and a higher percentage of women are better qualified than their male counterparts. However, it is anticipated that over time, the work force will become better educated and this can be expected to result in a degree of upward economic mobility.

Given the open nature of the economy and a reliance on a limited number of economic sectors, together with an ageing population, presents challenges in terms of the provision of affordable housing and social services including health and education. As an open, service-based economy, Barbados is vulnerable to external economic shocks as demonstrated by recent events such as the impact of the 9/11 incident, the financial crisis commencing in 2008, the spike in world food prices in 2010–11, the Covid-19 pandemic, the St Vincent ash fall and the impact of Hurricane

Elsa have all caused significant economic shocks to the country, impacting household incomes, unemployment and economic growth.

2.2 Future economic developments

The Terms of Reference call for a wastewater generation projection of 20-30 years. In accommodating this, a time horizon of 2050 has been chosen. It can be problematic making projections over such a time horizon as there are many unknowns that could affect the outcome. Projections over a shorter time horizon make some implicit assumptions, for example that consumer behaviour over the recent past can be used to predict outcomes in the short to medium term. Such assumptions would not necessarily hold for a longer time horizon. How Barbados' economy might develop over the next 30 years, what the impact of a Blue-Green economic transition might mean would be an open discussion. A way to account for uncertainty is to use scenarios. This report has not engaged in the development of future foresight scenarios. Such an exercise would be appropriate if it were to consider the water sector as a whole rather than just one part of the wastewater component. However, in order to examine the impact of possible future economic development four scenarios are used. The bases of the scenarios are discussed in Section 5.

Briefly the four scenarios are:

Scenario 1: Economic decline

In this scenario the economy is assumed to decline and there is a continuing decline in the population.

Scenario 2: No growth

In this scenario the current economic conditions remain unchanged and there is no economic growth and development and population levels remain static.

Scenario 3: Business as usual

This is similar to Scenario 2 but makes allowance for modest growth and development.

Scenario 4: Growth and Expansion

Under this scenario the economy growths, here is inward investment and development, and population increases.

For each of these there are changes in population, household size, consumption patterns and technology.

3. Climate Change

3.1 General

Climate change and climate variability is of growing concern and is expected to have cross-cutting effects. Rising sea levels coupled with more frequent and intense tropical storms and hurricanes are expected to put coastal developments, infrastructure, hotels, port and fishing facilities at greater risk. Much of the existing infrastructure was not designed to withstand such conditions. Intense rainfall conditions resulting in excess run-off into the marine environment would bring increased transportation of sediments and contaminants, covering coral reefs. Climate change is expected to reduce the island's available water resources considerably, with reduced availability affecting agriculture and driving the need for alternative additional sources such as desalination, which is energy intensive.

The projections of climate change for Barbados have been taken from the Climate Information website (https://climateinformation.org/create-report/) using the Site-specific Report generation facility. The information generated covers RCPs 4.5 and 8.5 using the Ensemble outputs for the time period 2041-2070. The time period was chosen as it covers the 20 – 30-year time horizon indicated in the Terms of Reference. Overall for most indicators the models indicate small changes as compared with the baseline, agreement on the change is highest with regard to temperature, with many models agreeing on an increase in aridity and a decrease in soil moisture. For precipitation, water discharges, and water run-off some of the models indicate a decreases, and for number of dry days and length of dry spell some indicate an increase.

Data taken from the World Bank Group's Climate Change Knowledge Portal (https://climateknowledgeportal.worldbank.org/country/barbados/climate-data-projections) indicates the following, which broadly match the data from Climate Information.

- Mean annual temperatures are projected to increase from 0.4°C to 2.1°C by the 2060's. Warming is projected to increase further by the 2090's from around 1.0°C to 2.1°C.
- Number of hot days is projected to increase substantially in turn increasing the frequency of hot days and nights that are considered "hot."
- According to the UNDP climate change profile, annual projections indicate that 'hot' days will occur on 27-67% of days by the 2060's, and 36-100% of days by the 2090's. Days that are hot for each season are projected to increase most rapidly during the months of September to November, occurring on 79-100% of nights in every season by the 2090's.
- Nights that are considered 'hot' for the annual climate of 1970-99 are projected to occur on 27-66% of nights by the 2060's and 37-99% of nights by the 2090's. Nights that are hot for each season are projected to increase most rapidly during the months of September to November, occurring on 79-100% of nights in every season by the 2090's.
- Projections of mean annual rainfall from different models are broadly consistent in indicating decreases in rainfall for Barbados. Annual projections vary between -53 to +18% by the 2090's with ensemble median changes of -7 to -18%.

The following graphs indicate the projected changes in climate indicators for Barbados, focusing on those which would have the greatest potential impact on water resources; temperature and precipitation. There is a small difference in the time horizons being 2040 – 2059.

3.2 Temperature

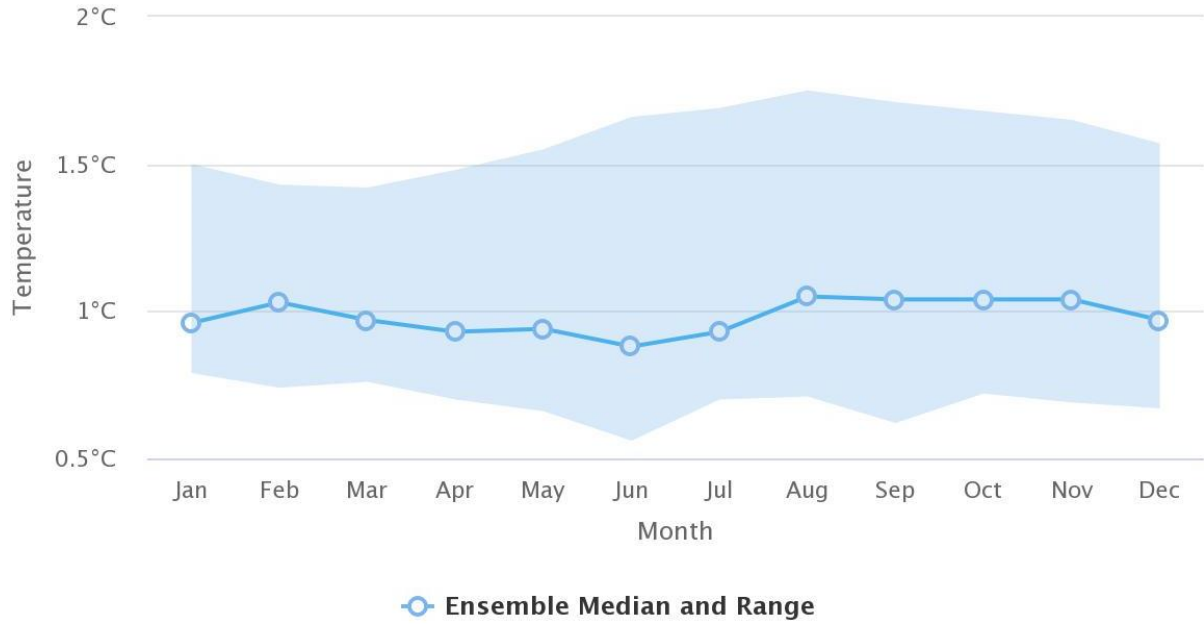


Figure 1: Change in Mean Monthly Temperature 2040-2058 RCP 4.5

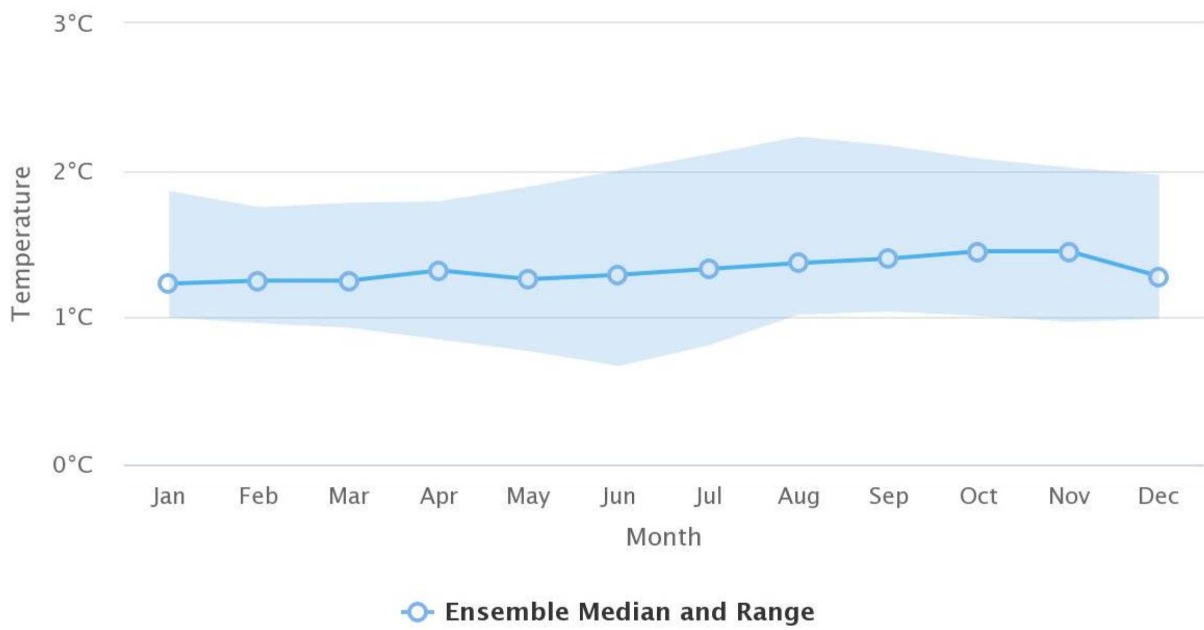


Figure 2: Change in Mean Monthly Temperature 2040-2059 RCP8.5

Figures 1 and 2 both show an increase in mean monthly temperatures. Although not calculated higher temperatures are likely to also lead to increased evaporation and evapotranspiration rates.

3.3 Precipitation

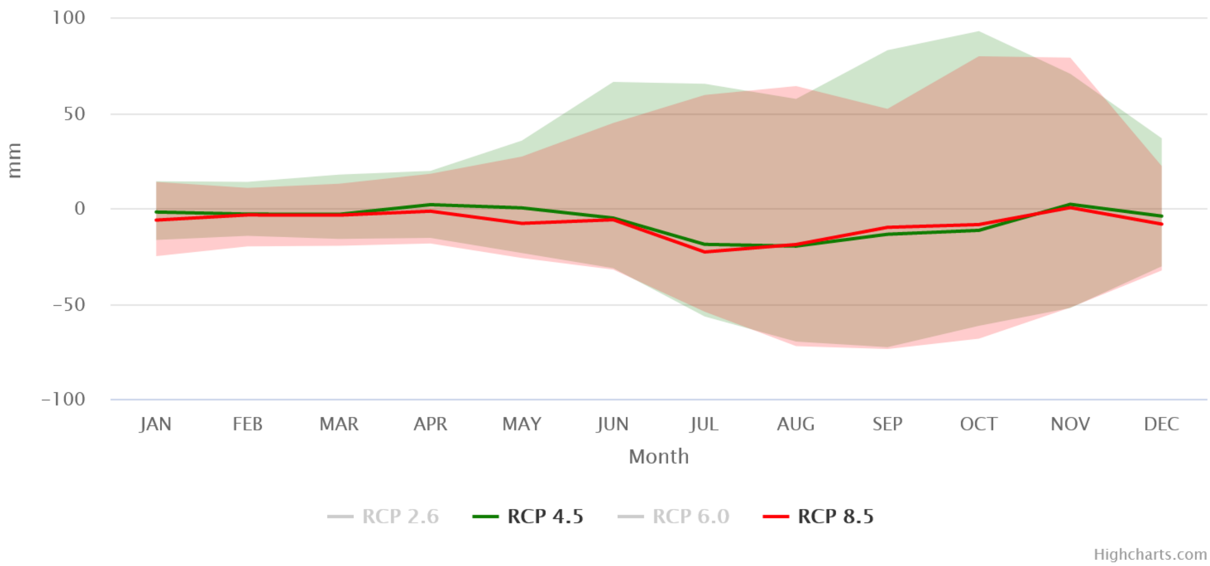


Figure 3: Change in Mean Monthly Precipitation for 2040-2059

The change in mean monthly precipitation indicate little change in mean and variability during the traditionally dry months of January through to June, but a decrease in mean and increased variability in the wet season Figure 3. In percentage terms the projected decreases look somewhat more dramatic. Figure 4 and 5 indicate the downward trend in mean annual precipitation with time for RCP 4.5 and 8.5 though the uncertainty increases with time.

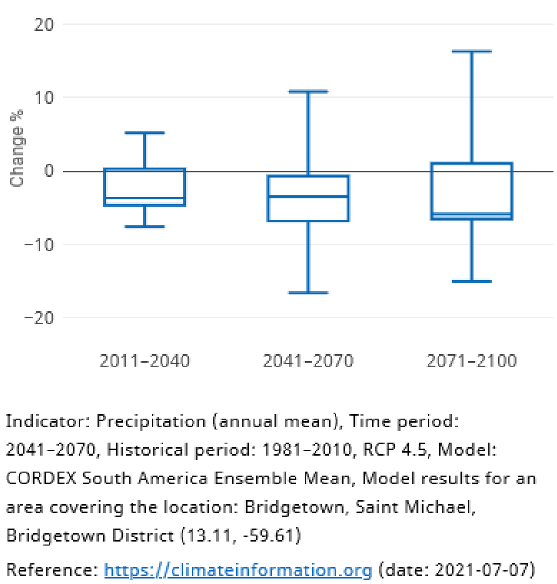


Figure 4: Annual Mean Precipitation RCP 4.5

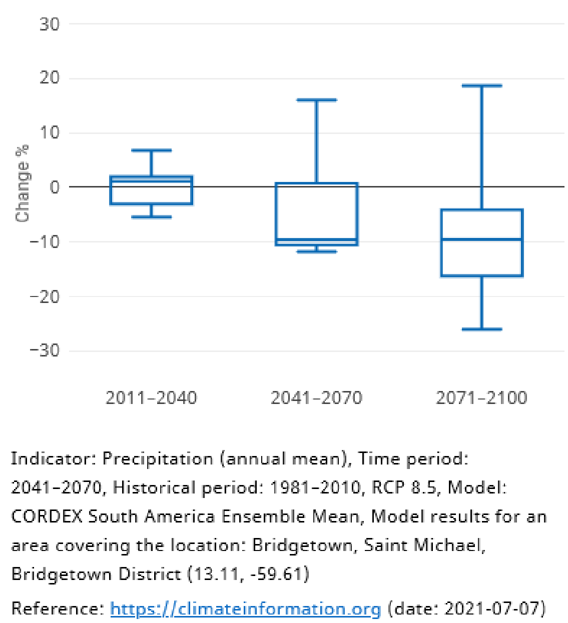


Figure 5: Annual Mean Precipitation RCP 8.5

The other significant precipitation indicators include those related to dry spells and drought conditions. There is a downward trend in the number of days with heavy precipitation and at the same time the maximum number of consecutive dry days increases under RCP 8.5 though there does not appear to be an increasing trend under RCP 4.5.

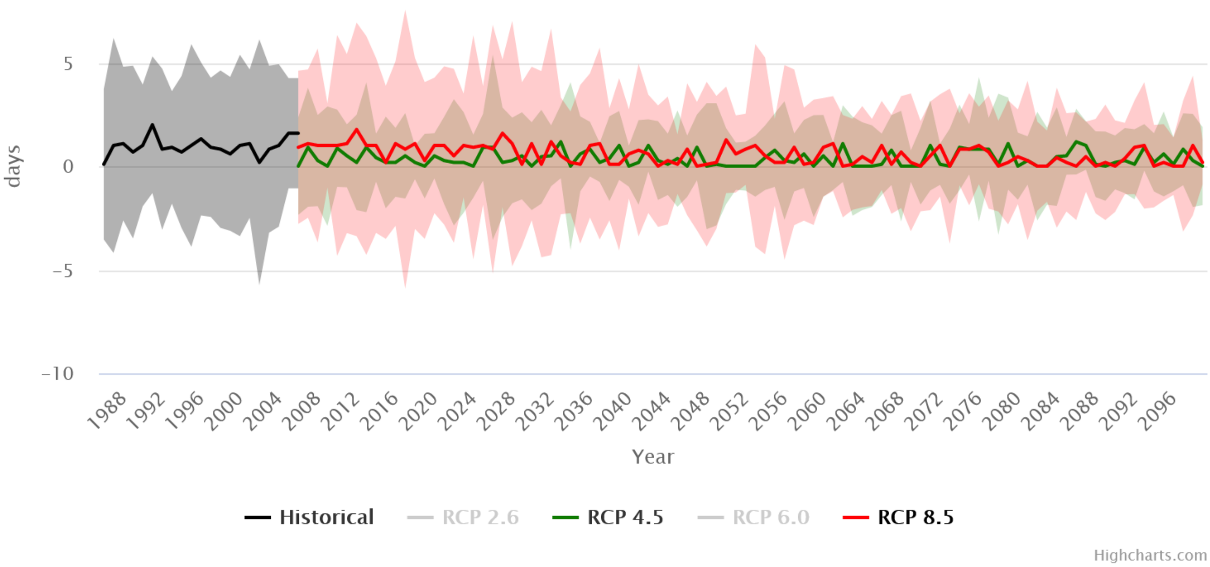


Figure 6: Number of days with very heavy precipitation for 2040-2059

3.4 Drought

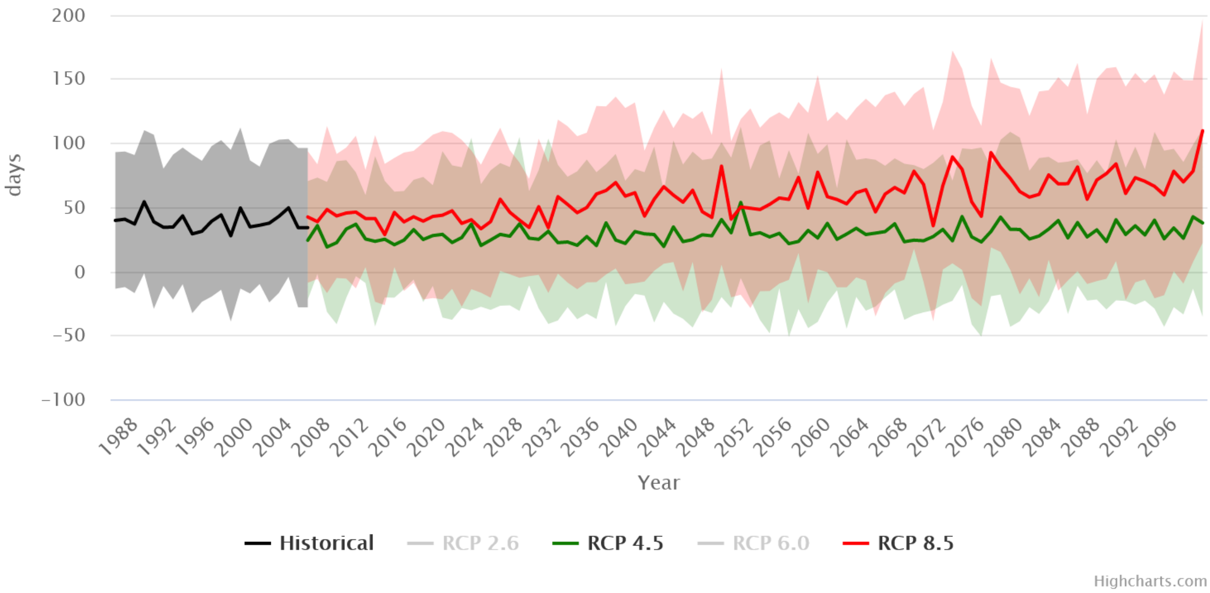


Figure 7: Maximum number of consecutive dry day for 2040-2059

The projected change in days of consecutive dry spells, under RCP 8.5 is more prevalent during the dry months with the range of value of projected change also being greater, indicating greater variability.

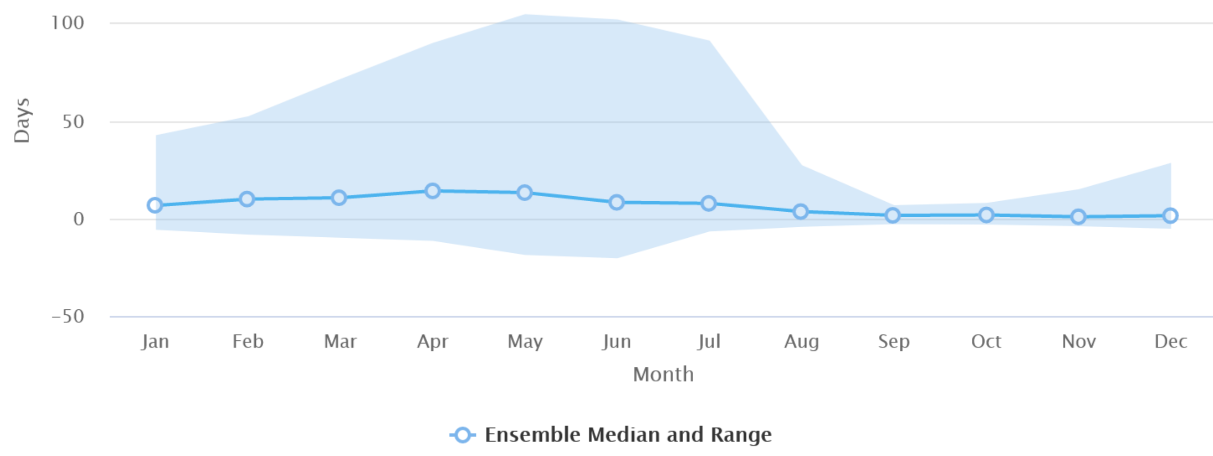
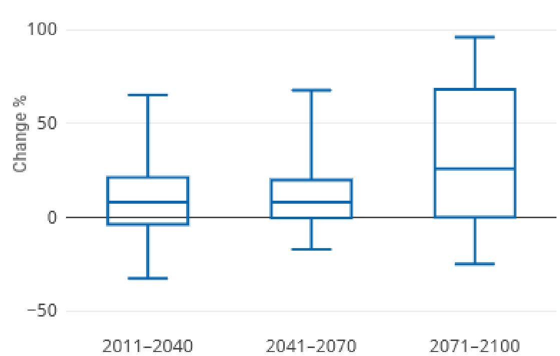
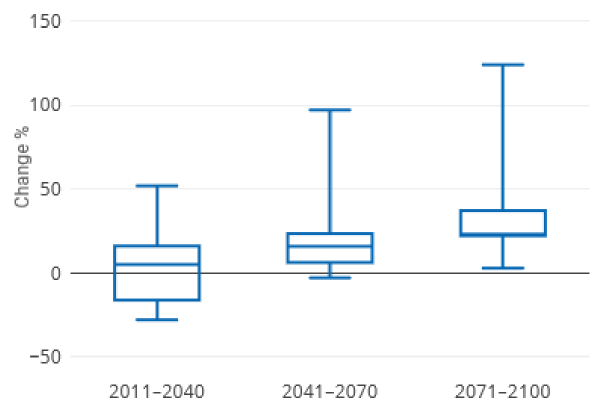


Figure 8: Projected change in days of consecutive dry spell for 2040-2059 under RCP 8.5



Indicator: Longest dry spell (annual mean), Time period: 2041–2070, Historical period: 1981–2010, RCP 4.5, Model: CORDEX South America Ensemble Mean, Model results for an area covering the location: Bridgetown, Saint Michael, Bridgetown District (13.11, -59.61)

Reference: https://climateinformation.org (date: 2021-07-07)



Indicator: Longest dry spell (annual mean), Time period: 2041–2070, Historical period: 1981–2010, RCP 8.5, Model: CORDEX South America Ensemble Mean, Model results for an area covering the location: Bridgetown, Saint Michael, Bridgetown District (13.11, -59.61)

Reference: https://climateinformation.org (date: 2021-07-07)

Figure 9: Longest dry spell RCP 4.5

Figure 10: Longest dry spell RCP 8.5

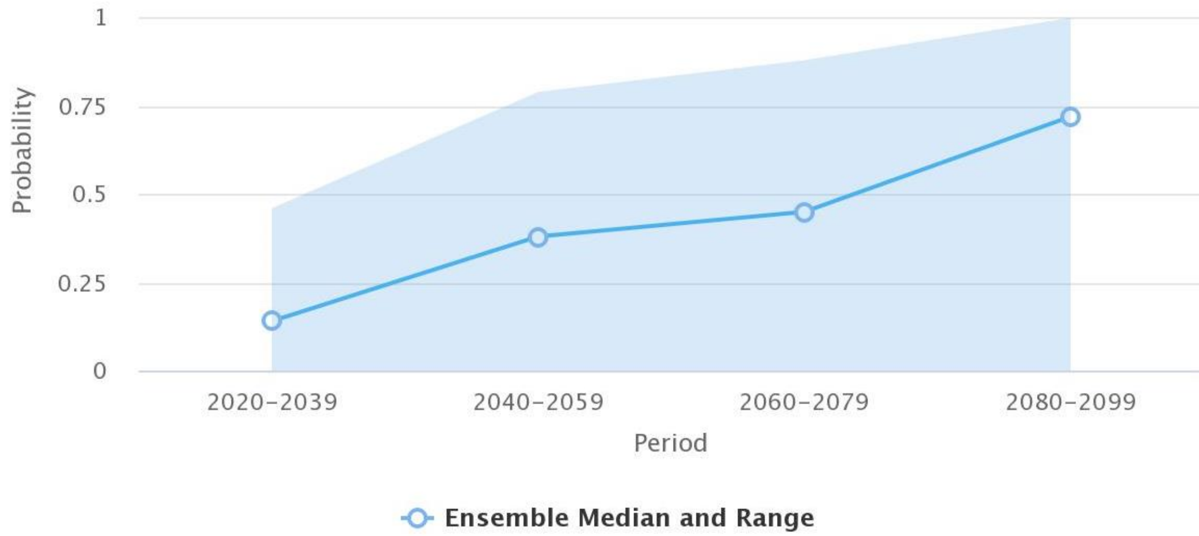


Figure 11: Projected change in annual severe drought likelihood for RCP8.5

3.5 Soil Moisture

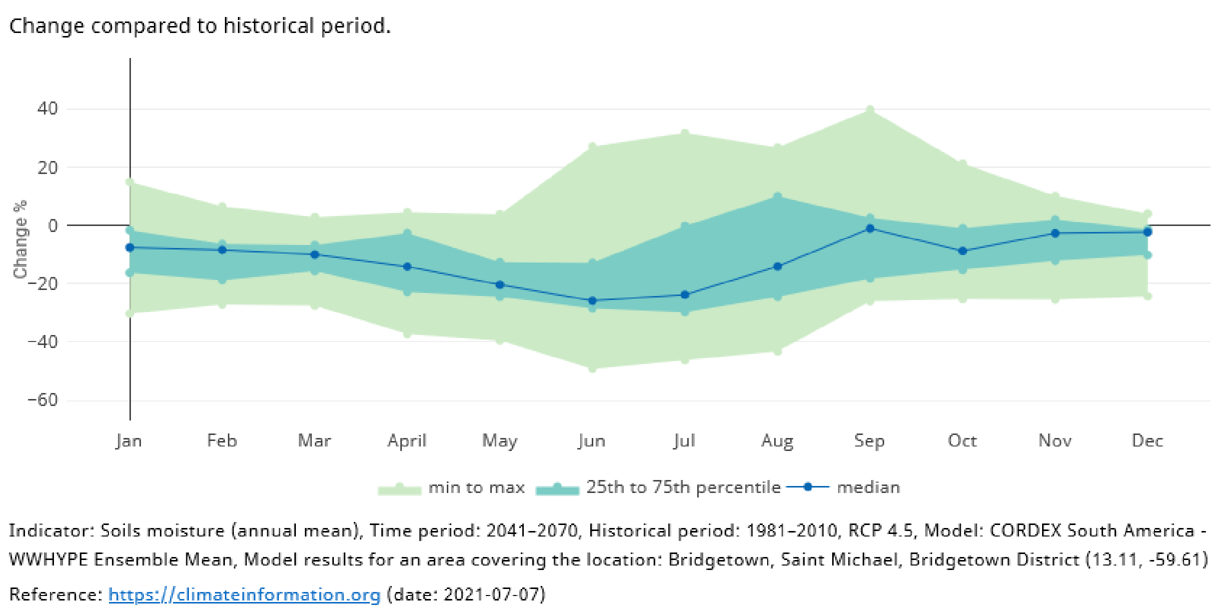


Figure 12: Change in monthly mean soil moisture for 2041-2070 for RCP 4.5

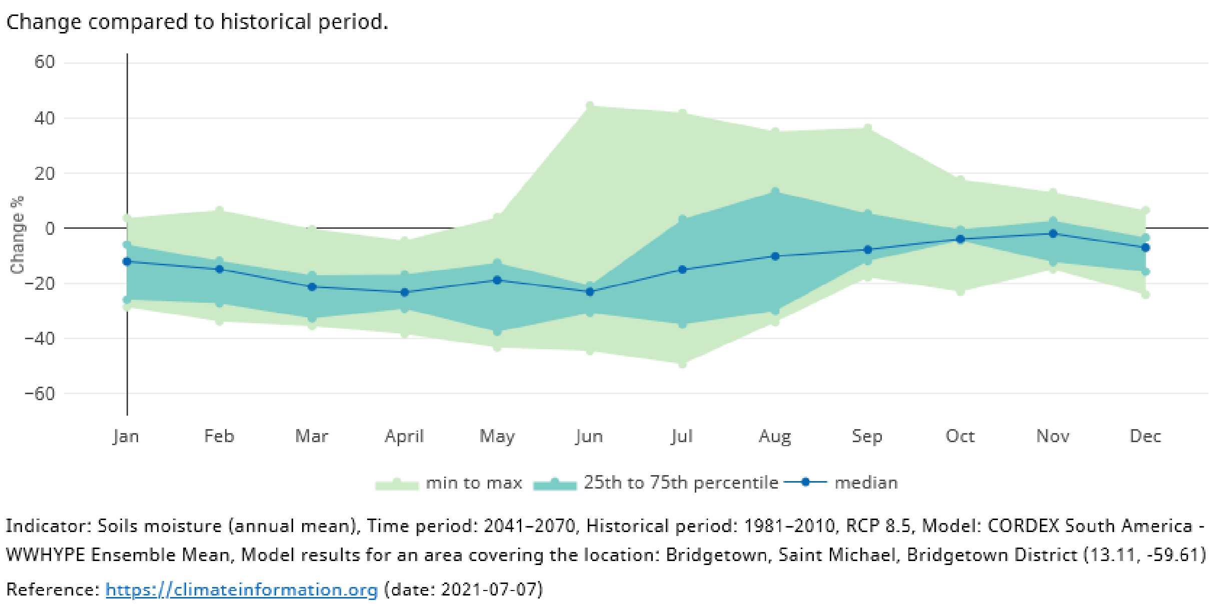


Figure 13: Change in monthly mean soil moisture for 2041 -2070 for RCP 8.5

3.6 Tropical Storms, Hurricanes and Storm Surges

Approximately 15% of Barbados' population live in areas that are below 5 metres above sea level. A significant area that is vulnerable is the Greater Bridgetown area. Studies have shown that the Greater Bridgetown area is already vulnerable to flooding and storm surges associated with tropical storm activity; in some areas, inundation could reach up to a kilometre inland. Sea level rise lies close to the global average of 3.1mm/year though in the case of Barbados this is slightly offset by the continued rise in land mass associated with the subduction of the Caribbean Plate under the North American Pate. Predictions of increases in storm/hurricane number and intensity under climate change are uncertain though the general assessment is that the overall number is unlikely to increase but that intensity will. The implication for Barbados is that the country is likely to experience an increase in the number of severe storms and hurricane activity. Such activity is likely to have associated with it storm surges and increased flooding.

In terms of impact on water resources storm surges are likely to have minor, localised impacts. Increased flooding may paradoxically have the effect of decreasing aquifer recharge. The terrain would not be able to absorb the intense amounts of rainfall and would result in increased run-off, a loss of recharge volume.

The effects would be felt more in terms of damage to infrastructure and economic disruption from winds and flooding.

3.6 Impacts on Water Resources

Figure 7 to 13 make the point that although changes in precipitation may be relatively modest on an annual basis, see Figures 2 to 5 when combined with the higher temperatures the dryness not only increases but the variability does as well. This has potentially severe consequences for Barbados' water resources.

The studies of the impact of climate change on Barbados' water resources are few in number, partly due to the poor understanding of the hydrogeological behaviour of the island' aquifers. A

Technical Report, produced by UWI-CERMES in 2016 as part of the Global-Local Caribbean Climate Change Adaptation and Mitigation Scenarios (GoLoCarSce) project, included an assessment of the impact of climate change on aquifer safe yields. This work, based on hydrogeological modelling using MODFLOW 2000, indicated that by 2050 under RCP 2.6 groundwater yields could be reduced to 26.9 Mm^3/year and 25.5 Mm^3/year under RCP 8.5, as compared to a no climate change estimate of between 65.7 Mm^3/year (based on an average annual rainfall of 1,420 mm) and 82.3 Mm^3/year (based on an annual average rainfall of 1,520 mm), depending on which estimate is used. This work was reported on at the International Climate Change Conference in the Caribbean: Integrating Climate Variability and Change information into Adaptation and Mitigation actions in the Caribbean Region, held in Trinidad, 9-12 October, 2017. The modelling work did not account for the potential impact of sea level rise or fluxes between the freshwater and seawater interface and therefore should be treated with some caution. Work (Cashman, et al., 2012) which took a mass-balance approach to changes in groundwater storage indicated that under all climate change scenarios aquifers would be progressively depleted. In other words, abstraction would be consistently greater than recharge. More recent work (Gohar, et al., 2019) which has looked at the impact of abstraction regimes on aquifer strage and yield have supported the view that under RCP 4.5 sustainable yields could be in the order of 31 Mm^3/year and 29 Mm^3/year under RCP 8.5. Previous work (Gohar & Cashman, 2016) investigated the impact of climate variability and concluded that one of the effects of greater climate variability could be to somewhat lessen the impact of climate change but that the effect would be minor and there would still be a sigificant decline in available groundwater supplies.

What has not been investigated is the potential impact of the increasing frequency and duration of dry and drought conditions on recharge and aquifer yields on short term runs. In the Easter Caribbean which includes Barbados, long term drought has been more frequent in the 20-year period (1999-2018) compared to the previous twenty years, but the trend is weak (Van Meerbeeck, 2020). Drought conditions, associated with El Niño cycles, have been experienced in 2009/10, 2012, 2015/16 and 2019/2020. By the end of 2019, Barbados had completed a 24 month period with below normal rainfall. The rainfall deficit had a severe impact on aquifer recharge and resulted in seawater intrusion into coastal aquifers and reduced yields. Modelling work for a PhD thesis entitled “Persistent Droughts in the Eastern Caribbean: Observed and Projected Impacts Under a Changing Climate” (Joyette, 2018) indicated that dry and drought conditions would occur more frequently in the future.

The overall implication of the available body of work suggests that sustainable aquifer yields could decrease by around 50% by 2050. This is troubling as the indications are that the level of groundwater abstraction is already at between 85-100% of the safe yield. Reliable figures of actual total abstraction are not available; the BWA has estimated that their own abstraction is approximately 47 Mm^3/year and that total abstraction could be as much as 62.5 Mm^3/year when other sources are included – abstraction from private wells mainly to support agriculture[1], recall that a lower estimate of safe yield given above is 65.7 Mm^3/year. The BWA abstraction, includes real losses – water lost to bursts and leakage from the water distribution system. Conservatively, real losses have been estimated to be 19.98 Mm^3/year or some 38% of production (BWA’s own figures). Even removing all losses from the distribution system, which is unrealsitic, would not be

[1] The BWA uses an estimate of 10.590Mm^3/year as an estimate of private abstraction. The figure is an estimate as although private abstractors are required to have a license from the BWA, they do not report their level of abstraction to the BWA.

sufficient to offset the imact of climate change on aquifer yields, again even if the impact has been over-estimated.

The effect of water scarcity, if not addressed, would be to lead to constrained demand and consumption and by extension less wastewater generation.

3.7 Impact on wastewater services

A changing climate would impact wastewater management through changes in temperature, precipitation patterns, sea level rise, and storm-related damages. The impacts depend on what wastewater management systems are implemented: stormwater drainage, centralised sewerage systems, or decentralised sewerage systems. Other non-climate factors, such as spatial concentration of populations, infrastructure, and economic assets, particularly in urban coastal zones, reinforce the societal impact of climate change, and can expose communities to a high level of hazard and damage potential. The lack of service provision with respect to sewerage systems contributes to increased levels of vulnerability to climate change impacts.

Increases in ambient temperature will lead to warmer air, soil and water temperatures and may lead to increases in biological activity and affecting corrosion rates in water supply and wastewater pipelines. For wastewater treatment works it has been suggested that higher temperature improves treatment efficiency due to the heat dependency of biological treatment processes. The effect of increased temperatures on greenhouse gases (GHG) emanating from wastewaters is not fully understood. Centralised wastewater treatment works require energy and, increased biological activity could result in greater energy demands. Secondly, increased biological activity associated with biogas from soak-aways, septic tanks, and other domestic treatment systems release more methane to atmosphere, thus contributing to a positive feedback loop and further intensifying atmospheric GHG concentrations.

The urbanised coastal areas are generally low-lying, sea-level rise would cause a rise in groundwater levels limiting the effectiveness of soak-away systems and restrict biological activity. This in turn will lead to elevated levels of beach and marine pollution; contribute to eutrophication of bathing waters and, create marine 'dead zones' making the areas less attractive to tourists.

Storm-related effects include surge damage, wind damage, and flooding. All three pose a direct threat to the wastewater infrastructure, and the services such as power supply on which they depend. If there is a loss of power, untreated sewage would be released into the environment.

In terms of the impact on consumption behaviour, there is very little literature that has considered climate change. If temperatures rise, there are the known effects of heat stress on the human body; the advice is to seek out cooler and or air-conditioned places. There would be some increase in drinking water consumption to keep hydrated. There may be some increase in the use of water for personal hygiene. Increases in relative humidity could amplify the effects of higher temperatures. However, there is very limited literature on how these effects might translate into water consumption increases. A recent study of consumption patterns in Belgrade, Calgary, Montreal, Seoul, Bahrain, Portland and Albuquerque (Dimkić, 2020) suggested that there is a linear correlation between temperature and consumption but that the strength of the relationship varies. The work also suggests an inflexion point above a threshold of 30ºC where the effect of temperature accelerates. Up to the threshold, for each 1ºC rise there is between 3% and 7% increase in drinking water consumption. However, it is total consumption that the study considers and does not distinguish for example between outdoor water use and indoor, which would contribute to wastewater flows.

4. Wastewater Services

4.1 Role of BWA

In 1980 the Barbados Water Authority Act came into force on the 8th of October and the BWA took over from the Waterworks Department as the Statutory Body responsible for supplying the island with potable water as well as the provision of wastewater treatment and disposal services. The BWA commenced operations on 1st April, 1981. Under the Act, the BWA is charged with responsibility for:

- The preparation of schemes for the development of water resources and for the supply of water and sewerage services and to construct, operate and maintain such services,
- Keeping under constant review the quality, reliability and availability of water supply and sewerage services and the rates to be charged for those services,
- The design, construction, acquisition, provision, operation and maintenance of sewerage works for the purpose of receiving, treating and disposing of sewage,
- Control and regulation of the disposal of sewage through sewerage plants that are not part of the Authority's system,
- The dissemination of information and advice with respect to the management, collection, production, transmission, treatment, storage, supply and distribution of water and where applicable, sewerage.

The Authority is also responsible for the monitoring, assessment, control and protection of the water resources in the public's interest.

4.2 Sewerage services

4.2.1 Existing services

Prior to the construction of the Bridgetown Sewage Treatment Plant in 1982, the disposal of sewage in Barbados was effected mainly through the use of septic tanks and soakways (shallow or 'suck' wells). In the tourism sector a number of hotels installed package treatment plants as have some businesses, and at present there are 68 package treatment plants in operation. There are two sewage treatment plants – the Bridgetown Sewage Treatment System (BSTS) and the South Coast Sewage Treatment System (SCSTS), operated by the BWA. The Bridgetown Sewerage System was commissioned in 1982 and services about one eighth of the town of Bridgetown with approximately one thousand five hundred (1500) connections. This is a secondary treatment plant with a short sea outfall. The South Coast Sewerage System was commissioned in 2003 and is a primary treatment facility also with a sea outfall. Due to problems with the sewage disposal pipeline the use of the Needhams Point outfall has been suspended and a new, short outfall constructed opposite the Graeme Hall Swamp. The South Coast Sewerage System can accommodate approximately three thousand connections, of which there are currently 2,000 active connections.

Information on the capacity of the two treatment works is confusing with various figures being quoted. The most recent work, a Baseline Study undertaken by Integrated Sustainability in early 2021 indicates the following treatment capacities:

Bridgetown Sewage Treatment Plant	Average Daily Capacity	9,000 m^3/day
South Coast Sewage Treatment Plant	Average Daily Capacity	9,000 m^3/day

Average Design Capacity 11,300 m^3/day

As the Baseline Report Notes the absence of inflow metering complicates the verification of the inflow volumes. Staff at the Bridgetown Plant believe that the inflow volume is of the order of 7,600 m^3/day, whilst for the South Coast Plant which has some inflow measurements daily flows for 2019 ranged from a low of 1,750 m^3/day to a high of 8,500 m^3/day with an overall average of 3,500 m^3/day. The Baseline Study (Integrated Sustainability, 2021) notes:

> *"the dry weather flows reported are much higher than the wet weather flows. The question is; what is causing the higher flows during dry weather? While tourism related wastewater generation is an obvious hypothesis, the influx of tourists in January would not be expected to generate a wastewater flow that is five times more than during wet weather conditions with fewer tourists. Our hypothesis is there are other sources of wastewater discharged to sewer during dry weather coinciding with the influx of tourists. This will require further investigation."*

Information provided by the BWA indicates the following breakdown of customers for the two systems, see Table 1.

Table 1: Breakdown of customers by rate schedule

Rate	Number of connections
M1 - Domestic	**2,892**
M2 - Commercial	**1,025**
M3 - Hotel	**74**
M4 - Government	**71**
M5 - Statutory	**64**
M6 - Port	**2**
Grand Total	**4,128**

All hotels are connected to the South Coast system, whilst the 2 Port connections are on the Bridgetown system. Commercial customers are in the majority on the Bridgetown system.

The Bridgetown Plant has a septage facility which receives material from private contractors emptying septic tanks. The facility receives approximately 115 m^3/day of septage. Organic solids, such as sewage sludge, from both Works are disposed of in agricultural area of former sugar lands located near the international airport.

The functioning of the Bridgetown and South Coast systems is covered by the work carried out by Integrated Sustainability and captured in their Baseline Study, and in their Conceptual Design Report (mid-July, 2021) and Feasibility Study Report (end August 2021), when they become available.

4.2.2 Proposed sewerage services

There have been plans to provide the West Coast of Barbados with a sewerage system, running from Shermans north of Speightstown to Bridgetown. There were two options for the treatment of the collected wastewater; treatment at a new plant at Fontabelle or treatment at Fontabelle and Porters. The treated water would be disposed through a mix of reuse and managed aquifer recharge, though provision was made for sea outfalls as a backup. A master plan was submitted in May 1998 and in March 2002 consultants submitted contract drawings and documents in accordance with the master plan. In 1997 a feasibility study for effluent reuse for Apes Hill, Royal Westmoreland and Sandy Lane Golf Courses was compiled. The master plan proposal was last considered in 2008 when the Cost-Benefit Analysis was revisited looking at the option of undertaking the project under a Public Private Partnership arrangement. The estimated wastewater flows were 23,200 m^3/day.

Concerns have been expressed over the high cost of implementing the West Coast Sewerage Project (WCSP) and this has been one of the reasons for it not having gone ahead. Recently a local company, Ecohesion, in collaboration with the BWA has put forward proposals to the Prime Minister which build on the WCSP for non-potable water generation, distribution, and intended uses. The recommendations in the paper include:

- Water reclamation pilot at the Bridgetown Sewage Treatment Plant (BSTP).
- Formalisation of the Coverley MBR utilisation.
- Satellite/decentralised BWA water reclamation plants for Zone A developments.
- Reuse grid-tie mains.
- Rainwater catchment on both a municipal and residential scale.
- West Coast Brackish Water Reverse Osmosis pilot.
- Possible solutions to address limitations on funding these ventures.

It is unclear what the status of this paper is and whether or not it might be taken forward. What it does do is expand the thinking on how wastewater services might be provided and the potential role of the private sector. Given the Government's stated intention of reducing the subsidisation of SOEs, including the BWA, there may well be some appetite in political circles for this type of intervention. However, caution is advised as the paper is no more than a concept at this stage and would require a great deal more development. For these reasons it does not form part of this assessment.

4.3 Impact of wastewater on environment

Aquifer vulnerability mapping was undertaken in 2009 by Burnside (R J Burnside and Associates Ltd, 2009) as part of the review of Barbados' groundwater protection policy. The Vulnerability Assessment used the DRASTIC methodology and concluded that nearly 80% of the area, excluding the Scotland District was either Very High or Highly vulnerable to aquifer contamination. Work by (Lewis, 1987) demonstrated that groundwater flux onto coral reefs on the West Coast varies spatially, fluctuates with the tidal cycle, and is generally higher in the wet season than in the dry season and that groundwater discharge was richer in nitrogen than in phosphorus probably because of the heavy use of nitrogen fertilizers. Wellington (1999) found that levels of nitrogen and phosphorous in the coastal area were twice and three times higher than at the pumping stations farther inland. This indicated that the dense coastal population, if unsewered and relying on septic tanks and suckwells, would add significant amounts of nutrient to groundwater. Monitoring and modelling work concluded that groundwater fluxes contribute 85% of the offshore nutrient load. Work by Baird (2017) concluded that groundwater fluxes contributed 85% of nitrogen and 53% of phosphorous loading to the offshore environment. On the basis of studies and evidence, it has been concluded that wastewater in groundwater is a major contributor to the discharge of nitrogen into the nearshore coastal area and that nutrients have had an adverse impact on coral reefs. Further evidence that coastal waters have been contaminated for a long time appears in a study conducted in 2003 that found that coral reefs have been impacted by eutrophication, an enrichment of water by nutrient salts, which has caused structural changes to the ecosystem off the Barbados coastline (Linton & Warner, 2003).

One of the reasons for the construction of the South Coast Sewage Treatment Works was to prevent the further deterioration of the bathing beach water quality, the coastal environment and in particular the coral reefs in that area. Regular coral reef monitoring has demonstrated that over time this has had the desired effect. On the West Coast, coral reefs continue to degrade, associated with the fluxes into the marine environment. All hotels along the West Coast are required to have on-site treatment facilities but even so the treated wastewater from the plants is usually disposed of through coastal infiltration wells. According to the Environmental Protection Department (EPD) approximately 70% of the plants meet the Marine Pollution Control effluent discharge standards though there are concerns regarding nitrate levels and chlorine residuals in the treated effluent produced by the plants.

In 1963 Barbados introduced regulations to protect its groundwater resources. Regulations while all developments in what were classed Current rregulations do not permit any development in Groundwater Zone1. In Zone 2 areas developments have to have septic tanks and soakaways (suckwells), and in Groundwater Zones, 3, 4 and 5 soakaways of at least 6 metres depth. However, for developments producing approximately 40 m^3/day of wastewater (approximately 50 dwellings or more), EPD now require the installation of package treatment plants though there are waivers being granted on a discretionary basis. Given the nature of Barbados' hydrogeology all groundwater flows, quantity and quality, affect the adjacent coastal marine environment. As a result, the Marine Pollution Control Act (1998) established discharge standards for all wastewater into the groundwater as well as the marine environment.

In 2020, a Government Green Paper "Water Protection and Land Use Zoning Policy" (MEWR, 2020) set out proposals for changes in the Zoning taking into account the emerging threats, proposing changes to the zoning and requirements for treatment of wastewaters. The Green Paper marks a move towards a system where contamination of the groundwater is controlled at source. This entails: 1) prohibiting suck wells as the primary means of wastewater treatment, 2) development of communal wastewater treatment facilities, and 3) provision of guidance for wastewater treatment. The proposed new Zones A – E have been incorporated into the National Physical Development Plan. The Green Paper also proposes that coastal areas would now be designated as Zone D – Recharge Contributing Area where wastewater disposal regulations will apply. Under the revised Groundwater Zoning Policy though, it will no longer be permitted to dispose of wastewater directly into suck-wells and some form of treatment will be required. The level of treatment will depend on the nature of the wastewater generated, as well as the location of the property (proximity to the ocean or BWA groundwater intake), location relative to sensitive marine ecosystems.

4.4 Management of wastewater services

4.4.1 Management arrangements

The management of wastewater services falls under the Director of Engineering, who has eight sections reporting to them. In total the Engineering Department consists of over 400 persons. Wastewater is one of the sections reporting to the Director. A recent internal discussion paper noted that the managerial span of control was too wide and is inefficient and ineffective. It also notes that recently the BWA has lost a lot of knowledge and experience as senior engineers were lost through retirements and attrition. Prior to 2017, the Wastewater Section was headed by an

Engineer then in 2017 the Wastewater Section was removed from the Director of Engineering's control and a manager of Wastewater was appointed. However, in 2018 as part of the Government initiative to reduce expenditure on SOEs, an evaluation of staffing levels was carried out. As a result, the post of Manager Wastewater was abolished and the section added back to the portfolio of the Director of Engineering.

Currently the Wastewater section is managed by two engineers, one responsible for the Bridgetown and the other for the South Coast wastewater systems. Both report to the General Manager of BWA though they do engage routinely with the Director of Engineering.

Whilst this arrangement appears to be working it is considered less than ideal and contributes to the inefficient and ineffective management as noted above. Having a section that falls under one manager but reporting to another has the potential to create confusion, dilutes managerial responsibility and limits strategic decision-making.

The Integrated Sustainability Feasibility Report (2021) contains a number of suggestions to improve the management of wastewater services including capacity building, data management and moves to proactive operation and maintenance. These are important considerations and should be given serious consideration.

4.4.2 Budgets and finances

The Wastewater section is reported to have its own operational budget, prepared jointly by the two Engineers in charge. Budget expenditure reconciliation is done by the Accounts section on a quarterly basis and provided to the Wastewater Section's Engineers who then reconciled actual against planned expenditure. There are no performance targets for the Section, though recently operational targets have been set internally. With respect to capital expenditure budgets, these are prepared annually based on prioritisation decided on internally taking into account aspects such as impact and consequences. The capex budget includes major replacement of machinery and equipment as well as any work or extensions to the collection systems as well as work on the two treatment plants. The annual capital and operational budgets are forwarded to the Director of Finance for consolidation into the BWA's overall budget and three-year capex budget. All this suggests a focus on immediate or short-term operational objectives. There appears to be a lack of strategic thinking regarding the provision of wastewater services and hence the development of multi-year capital expenditure budgets.

The expenditures attributed in the General Ledger to wastewater services are shown in Table 2. The jump in expenditure in 2018 and 2019 can be attributed to the costs associated with dealing with the sewerage problems on the South Coast, when due to broken sewerage pipes raw sewage was running on the streets. There were also equipment failures in 2019 at the Bridgetown Treatment Plant, which incurred additional expenditures. Overall the expenditures on items such as overtime, materials and supplies, repairs and operational expenses for 2018 onwards reflect the additional expenditures to deal with the build-up of problems believed to be associated with inadequate maintenance.

Table 2: General Ledger Expenditures (Bds$)

	2017	2018	2019	2020	2021
Common	1,840,177	2,381,389	1,678,805	1,376,292	1,101,155
South Coast	2,016,905	3,999,790	11,240,80	2,210,309	1,700,811
Bridgetown	2,410,572	2,752,079	4,294,441	5,281,991	5,173,409

Total	6,267,655	9,133,259	17,214,05	8,868,593	8,014,311

4.4.3 Staffing

There are a total of 24 persons stationed at the Bridgetown Works and 13 at the South Coast Works. In addition, there are another 4 persons who not allocated specifically to either of the Works and there are 2 vacant posts. A total establishment of 43 people.

Post	Bridgetown Works	South Coast Works	Overall / Shared
Artisan Electrician	2	1	
Artisan Fitter	1	2	
Artisan Painter	1		
Artisan Plumber	1		
Clerical Officer			1
CCTV Operator		Vacant	
CCTV Assistant		1	
Field Officer	1		
Handyman Sewerage	3	1	
Laboratory Technician	Vacant		
Labourer	1	2	
Lorry Driver	3		
PSO Sewerage	7	5	
Secretary			1
Section Leader Electrical		1	
Sewerage Foreman	1		
Senior Engineer			2
Superintendent Works	1		
Truck Assistant	2		

One of the vacant posts is that of Laboratory Technician, based at the Bridgetown Works. This should be of concern as it implies that there is no proper monitoring of the efficiency of the wastewater treatment. According to the Senior Engineers, there is a need for a further 4 operators (PSO Sewerage) but that apart from the Laboratory Technician vacancy they feel that the staffing is adequate in terms of numbers for the current configuration. However, it has been indicated that to improve the efficiency of the Works, the addition of a Mechanical/Electrical Technician would be beneficial.

Both Works are of older design types and rely on mechanical equipment and processes with no monitoring instrumentation or use of more modern technologies. This is reflected in the staffing structure and posts. Any upgrading of the two Works should require a re-evaluation of staffing requirements and the likely upgrading of qualifications and training requirements for operational staff. The changes in staffing requirements were not addressed in any of the reports either by AECOM or Integrated Sustainability. However, it is understood that BWA are pursuing through the Caribbean Wastewater and Sewage Association Inc. training and certification of their operatives.

The operation and maintenance of the collection systems is unlikely to change and hence the staff qualifications are unlikely to change as well, though there may be some additional requirements. Any expansion of the collection systems though may require additional labour input.

At present the basic staff cost, excluding overtime and other charges is approximately Bds$2.300 million per year. An assessment of the future staffing requirements of the two upgraded works has been made and it is estimated that this would increase the staff complement by an additional 15 posts. This would increase the annual staff budget to Bds$3.400 million per year.

4.5 Tariff structure & income generation

4.5.1 Tariffs

The Barbados Water Authority has a six-tier rate schedule for customers, as shown in Table below;

Rate Schedule	Description
M1	Domestic
M2	Commercial
M3	Hotel
M4	Government
M5	Statutory Bodies
M6	Port

There is no separate rate for Agricultural customers, and they are charged at the Commercial rate.

When it comes to charging for water services the Authority operates an increasing block tariff structure; the more that is consumed the higher the unit rate. This is supposed to encourage efficient water use and at the same time by setting a low initial rate it is supposed to benefit low-income customers. Charges are set separately for water and sewerage services. Changes in tariffs were introduced on 1st July 2009 and then again 1st August 2018. In August 2018, the Government introduced the Garbage and Sewage Contribution levy with the intention of improving the finances of the Sanitation Service Authority (SSA) – which got the greater share of the levy, and of sewerage services, in the light of the operational problems being experienced. The GSC levy is charged to all customers whereas previously only those connected to the sewerage system were charged. In August 2019, an amendment to potable water charges was introduced for commercial customers to eliminate the anomaly of residential customers falling into the highest tariff band being charged more than commercial customers.

Consumption Band (over 30 days)	Water		Sewerage	
	Residential (M1)			
	Up to 30/06/2009	**01/07/2009 – Present**	**Up to 31/07/2018**	**01/08/2018 - Present**
0 – 8 m^3	Bds$1,55/$m^3$	Bds$2.48/$m^3$	⅓ of water rate for connected customers	Bds$0.25/day for all customers
9 – 20 m^3	Bds$1.94/$m^3$	Bds$3.10/$m^3$		
21 – 40 m^3	Bds$2.91/$m^3$	Bds$4.66/$m^3$		
> 40 m^3	Bds$4.86/$m^3$	Bds$7.78/$m^3$		
	Commercial (M2 – M6)			

	Up to 30/06/2009	**01/07/2009 – 31/07/2019**	**01/08/2019**	**Up to 31/07/2018**	**01/08/2018 - Present**
0 – 39 m^3			Bds$4.66/$m^3$		
40 m^3 – 12,000 m^3	Bds$2.91/$m^3$	Bds$4.66/$m^3$	Bds$7.78/$m^3$	⅔ of water rate for connected customers	25% of water rate for all customers
> 12,000 m^3			Bds$4.66/$m^3$		

The lowest tariff band has been referred to as being the Hygiene Needs, the next band the Normal Needs, the next Discretionary Use and the highest band the Excessive Use band. The increase in tariffs that came into effect on 1st August 2009 is believed to be a compromise between what the BWA had first sought – 100% increase and what was accepted, being a 60% increase in charges. At the time the then General Manager indicated that the Hygiene Needs tariff band represented 80% of cost of water, the Normal Needs 100%, Discretionary Use 150% and the Excessive Use 250% of the cost of water.

Tariffs are revised on an ad hoc basis, through the BWA Board to the Minister and approved by the Cabinet. The rates do not relate to the financial position of the Authority. Eventually, the Authority is supposed to be regulated by the Fair Trading Commission (FTC) with respect to the setting of tariffs and charges. There is no indication as to when this might come into force, even though the legislative instruments are in place. At present, the FTC only regulates the BWA with respect to General Conditions of Service.

4.5.2 Income Generation

In 2020 Cowater Consultants presented the "A Cost of Services Study and Tariff Proposal: Draft Business Plan" Report for BWA. The report noted that:

"According to the analysis of the financial performance of BWA, the current tariff covers only 87% of BWA's total operational expenses that include the depreciation. Given that the current tariff applied since 2018, the increase in tariff does not solve the financial challenge for BWA. It is actually strengthening BWA's dependency on the support from the government to cover its increasing net losses."

It went on to say that the breakeven daily charge for wastewater service would have to be Bds$1.74 and that with a fixed charge of Bds$0.25 per day the sewerage service is heavily subsidised by the water service. The Report notes that there are deficiencies in BWA's financial record keeping, which complicate the allocation of costs to functional activities such as wastewater service;

"It is strongly recommended that the BWA consider the adoption of a comprehensive financial[2] *management system that will enable a detailed examination of costs. Costs should be allocated first to the BWA functionalities e.g. water production, wastewater collection, customer service etc., and then to the cost elements within each of these functionalities e.g. power, labour, materials etc. The functionality headings could be further broken down to each treatment facility or distribution zone. Precise marginal costs could be calculated for each treatment works, as could*

[2] The BWA has indicated that it has a comprehensive management financial system which captures the functionalities mentioned. However, breaking down the cost by zones, will required additional General Ledger accounts in addition to additional staff monitoring portfolios for each zones.

the cost of water distribution in each zone and the cost of wastewater collection in each sewer zone."

These may have been addressed in the interim through the implementation of a Management Information System.

However, based on the information available the Report concluded that the BWA could not be considered as financially sustainable and noted that both the OPEX Cover Ratio and the Working Coverage Ratio indicated a worsening situation. The Report then goes on to examine a number of scenarios regarding the structure of tariffs and tariff increases. It does not make specific recommendations but rather provides information on which the BWA could make a decision. All though include the need to reduce costs whilst at the same time increasing revenue. There were no wastewater service specific proposals.

The change in charging for wastewater service introduced in 2018 has substantially increased the wastewater related income. Whereas prior to this only those connected to either the Bridgetown or South Coast sewerage systems were charged for the services, now all BWA customers are charged. In 2017, the amount collected in sewerage charges was approximately Bds$10 million, the amount collected in 2019 from the same customer base (~4,000 customers) was Bds$5 million but there are approximately 110,000 customer connections in total, made up of both domestic and non-domestic customers.

Income generation from the two existing systems has been calculated from records provided by the BWA covering the period February 2017 to May 2021. This includes the period up to 31 July 2018 when sewerage service charges were levied as a percentage of volume of water supplied and from the 1st August 2018 the introduction of the GSC levy. The records provided have enable a breakdown of the billed income by system (i.e. Bridgetown or South Coast), year, month and rate schedule. It also allows the identification of inactive accounts. These figures have been built into the financial and economic model.

4.6 Operational costs & budgeting

Cost information is required to be able to undertake the financial modelling, based on past expenditures and on projected expected expenditures. The following cost information was requested on the BWA.

Data Requested	Status
Future of wastewater services	Discussions have been held with Dr Sealy regarding future plan for wastewater services and ongoing initiatives. Discussions were also held with Mr Brian Stuart Senior Engineer with Wastewater Services
BWA Financial Statements for 2018 - 2020	Not all provided to date, we understand that they are not available. We have copies of Financial Statements up to 2017 and some information for 2020.
Financial information from 2018 detailing expenditures on operations and maintenance costs for wastewater services only. Also details of expenditures for emergency repairs and replacement costs associated with the	Copies of the General Ledger entries for the years 2017 to present have been provided. Separate information on staffing is reported on below.

collection, treatment and disposal of wastewater systems (BTSTW & SCSTW).	The General Ledger aggregates electricity costs. Disaggregated information has been sourced from analysis of accounts done as part of an internal renewable energy feasibility study. These figures have been correlated with copies of monthly electricity accounts for the period January 2017 – September 2020. No separate information on emergency repairs has been provided.
Historic and projected capital expenditures on only wastewater services projects, including the total amount, the phasing of expenditures, the source of financing, associated grace period, interest rates, and repayment schedule. Information to include any relevant Cabinet submissions for the expansion of the collection systems.	The Ministry of Finance, Economic Affairs and Investment has stated that there are no outstanding loans in respect of wastewater services. Information on planned BWA expenditures is sourced from the Capex Budget January 2020.
For existing customers served by both the BTSTW and SCSTW, information from 2015 on existing wastewater tariffs, income generated from customers served and numbers of wastewater customers, broken down by residential and commercial, and by serviced area i.e. BTSTW or SCSTW. Information on any sales of treated wastewater to customers.	Information from February 2017 was provided. Analysis of the data provided has enabled the extraction of the relevant information. There are no sales of treated wastewater.
Details of the monthly volume of water supplied to customers serviced by the BTSTW or SCSTW since 2015, broken down by customer category.	Information from February 2017 was provided. Analysis of the data provided has enabled the extraction of the relevant information.
Details of water supplied to customers who might be eventually connected to an expanded wastewater collection system of the Bridgetown STW or South Coast STW.	Discussions with the 2 Senior Engineers responsible for the operation of wastewater services has provided information on their perspective of planned expansion of the collection systems. Further information on the possible connection of additional customers has been collected from key informants and Government announcements.
Monthly volume of water supplied for agricultural usage since 2015.	There is no separate billing of water for agricultural purposes, it is listed as part of the Commercial rate schedule. No separate estimate can be made with the information available. BWA makes its own estimate of the level of private groundwater abstraction.
Data on the monthly wastewater flows entering the BTSTW and SCSTW since 2015.	There are no inflow records for the Bridgetown Plant. Inflow records for the South Coast Plant giving the average daily inflow by month

	between January 2019 and May 2021 were provided.
Copies of maps, diagrams or figures showing the extent of coverage of the wastewater collection systems.	Copies of maps and layout for the Bridgetown system were sourced from an Integrated Sustainability report and CAD files provided by BWA.
Information on the approved staff complement for the wastewater division including filled and vacant posts, level/position/grade, and associated pay scales together with allowances. Please also indicate what the full cost of employment is for each post – not just remuneration, if known.	Information on staff complement, vacancies, pay scales and allowances was provided. An assessment of additional posts was provided through discussions. No full cost of employment was provided but can be estimated.
Whether there have been provisions made in the Welfare services for those unable to pay water bills particularly during the current socioeconomic crises as a result of the COVID19 disease pandemic and the burden of the St Vincent ash fall.	BWA has not made any special arrangements. This is dealt with by the Welfare Services.
Data on areas affected by water outages, restricted access to water (and the reason), duration, numbers of persons affected (by area) for 2020/2021.	Discussions were held with Operations personnel and information was shared. Exact figures of numbers affected, duration are not collected but an overview was provided.
Complaints about water shortages, low pressure, restrictions for 2020/2021	No details were provided but a general overview was provided.

In summary, operational costs including a breakdown of electricity have been taken from information from the General Ledger, and other sources. These are used in the model as the average and marginal costs associated with water supplied. The following tables summarise the information received, excluding electricity costs.

Table 3: General Ledger Expenditures - Bridgetown Sewerage System

Description	2017	2018	2019	2020	2021
Basic Salaries, Wages & Allowances	1,291,362.45	1,361,315.65	1,389,996.77	1,815,194.79	2,007,499.61
Travelling	19,293.94	48,344.63	35,392.52	30,126.80	29,858.45
Task Work	-	4,609.25	-	2,598.60	1,281.00
Overtime Expense	452,818.92	516,046.02	712,026.53	943,336.48	800,019.23
Other Payroll Charges	245,323.45	259,377.66	221,720.22	296,546.12	386,106.01
Equipment Rental Expense	2,720.00	43,725.50	80,505.87	16,039.51	9,372.53
Conference & Meetings	-	450.00	-	7,604.50	-
Tools & Other Equipment	1,699.74	40,111.86	88,848.34	51,728.59	126,747.21
Training	-	6,408.76	-	-	-

Transportation	252,556.58	254,951.05	257,383.33	167,224.05	201,022.07
Books & Periodicals	552.00	-	-	420.00	1,080.00
Materials & Supplies	17,746.89	24,488.37	59,764.62	203,293.01	129,790.76
Maintenance & Repairs	99,803.16	131,009.00	155,251.35	256,104.12	1,240,579.87
Operational Expense	26,694.92	61,241.76	1,293,551.85	1,491,775.37	240,053.23
Total	**2,410,572.05**	**2,752,079.51**	**4,294,441.40**	**5,281,991.94**	**5,173,409.97**

Table 4: General Ledger Expenditures South Coast Sewage System

Description	2017	2018	2019	2020	2021
Basic Salaries, Wages & Allowances	717,149.38	1,102,577	1,885,313	829,190	745,832
Travelling	14,837	3,221	16,088	12,496	9,355
Task Work		47,192	2,196		
Overtime Expense	424,754	697,600	1,232,943	481,926	362,251
Other Payroll Charges	114,242	221,691	287,024	143,063	139,858
Equipment Rental Expense	6,011	92,635	43,237	88,112	9,019
Conference & Meetings		450	3,800		
Tools & Other Equipment		2,153	3,265	20,561	45,210
Training		2,335		25,142	
Transportation	189,417	190,528	192,947	166,543	201,022
Books & Periodicals					
Materials & Supplies	47,394	618,981	966,306	115,698	54,930
Maintenance & Repairs	139,984	74,174	2,287,740	158,735	19,398
Operational Expense	363,113	946,248	4,319,941	168,838	113,931
Total	**2,016,905**	**3,999,790**	**11,240,805**	**2,210,309**	**1,700,811**

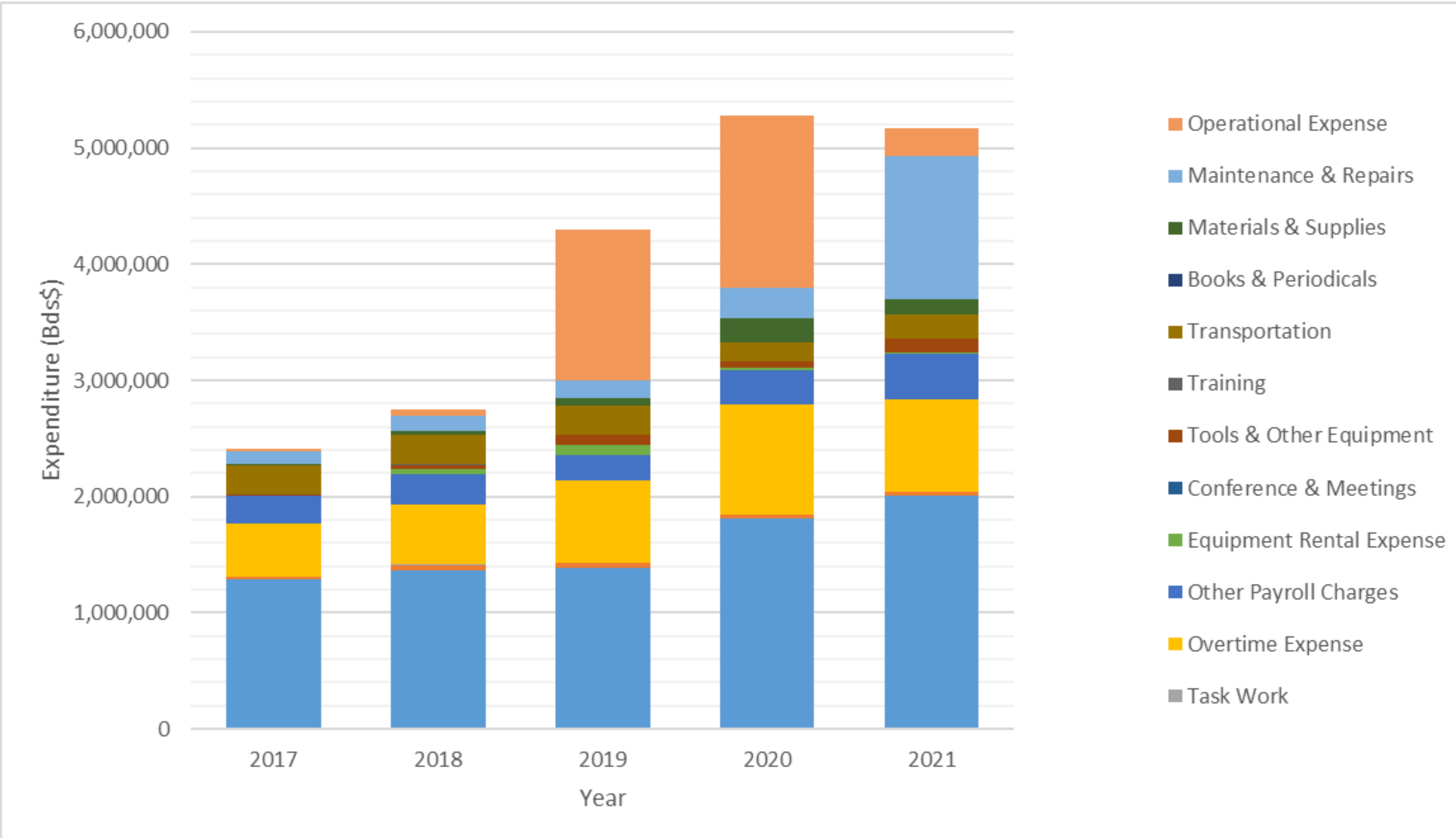


Figure 14: Bridgetown Sewerage System Expenditures

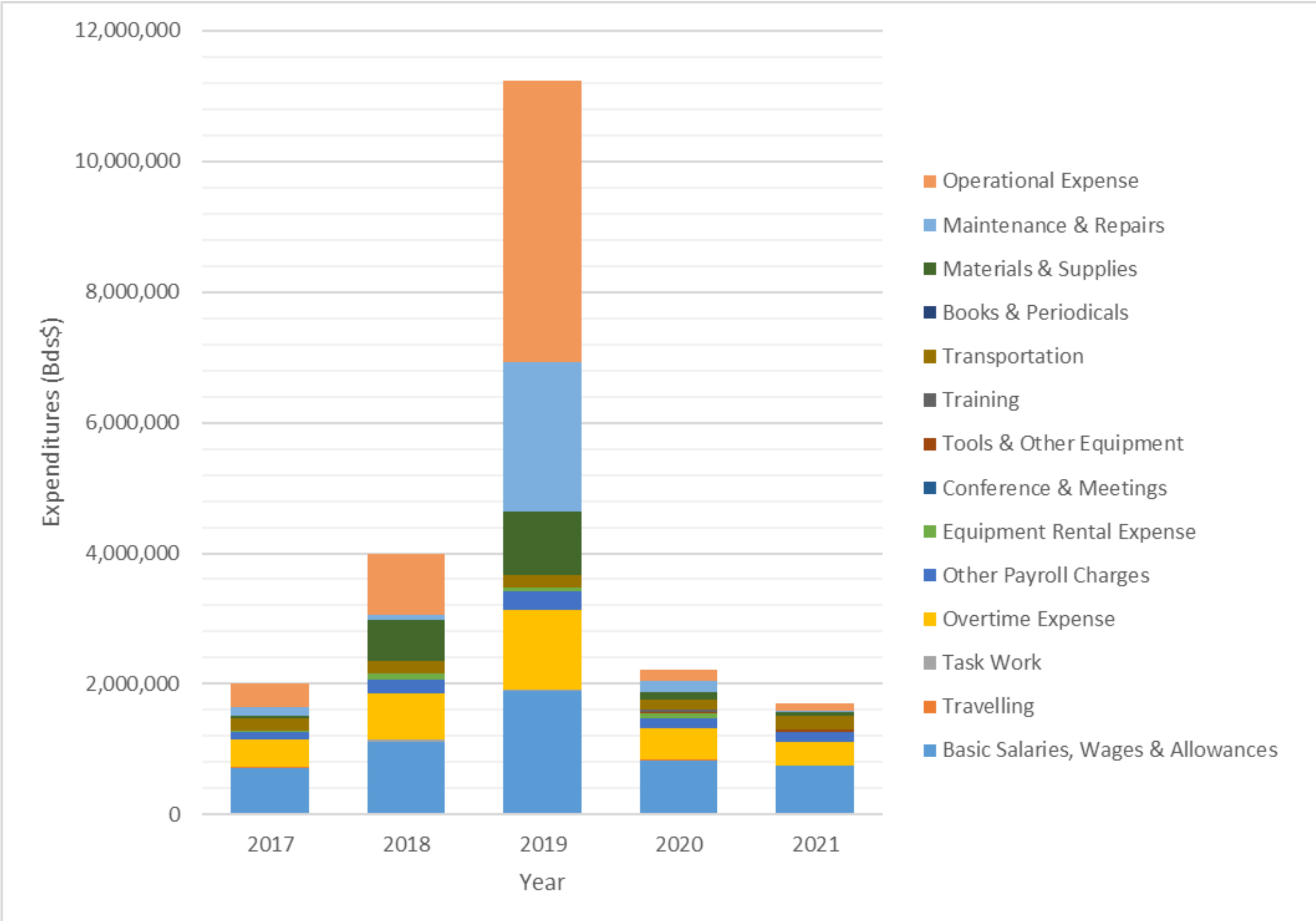


Figure 15: South Coast Sewage System Expenditures

4.7 Historic Capital Expenditures

The Ministry of Finance, Economic Affairs and Investment have indicated that there are no outstanding capital loans in respect of wastewater services..

4.8 Planned Capital Expenditures

Using information from the BWA Capex Budget 2020 and recent Requests for Proposals, the following planned capital expenditures have been identified, the amounts and timings to be confirmed by BWA. These exclude the estimates for the upgrading and extension of the Bridgetown and South Coast systems. The estimates for these will be taken from the Conceptual Design Report.

Table 5: Planned Capital Expenditures

Description	Amount (Bds$)	Funding Source	2022	2023	2024
South Coast Permanent Outfall	12,000,000	IFI Loan[1]		12,000,000	
Sewering Chapmans Lane & Fontabelle	20,140,000	GSC[2]	10,000,000	10,140.000	
Sewering The Belle Tenantry	4,028,000	GSC	4,028,000		
Maintenance upgrades	1,080,000	Internal	300,000	480,000	300,000
Network Repairs Bridgetown	2,000,000	GSC	600,000	700,000	700,000
Network Repairs South Coast	2,000,000	GSC	600,000	700,000	700,000
SCSTP Wastewater Pump	800,000	GSC	400,000	400,000	
Rehabilitation of wet wells; BSTP & River Road	100,000	GSC	100,000		
Renovations BSTP	20,000	Internal	20,000		
Renovations SCSTP	20,000	Internal	20,000		
Upgrade Laboratory BSTP	40,000	Internal	40,000		
Upgrade Office Building BSTP	300,000	Internal	100,000	200,000	

1 International Financial Institution (IFI) e.g. Caribbean Development Bank

2 Garbage and Sewage Contribution (GSC) levy

In addition to the capital expenditures identified in Table 5 there are other potential capital expenditures which may or may not be realised. The potential developments are described in Section 5.2.1 and 5.2.2, however, the estimated capital expenditures are given in the Table below.

5. Wastewater scenarios

5.1 Overview

As described in Section 4.2 the Bridgetown sewerage systems services a core area of Bridgetown and provides secondary treatment before treated water is disposed via a marine outfall. The South Coast sewerage system services the coastal strip and provides primary treatment before disposal via a short marine outfall. It is understood that both Plants are to be upgraded to the level of advanced tertiary treatment to enable a greater range of potential reuse option for the treated water. Treated water will not be disposed of into the marine environment. Instead, the options are to reuse the water for agricultural purposes and/or managed aquifer recharge. At this stage, direct potable reuse is not considered to be an option. Furthermore, although the level of treatment to be provided will increase, it is only the capacity of the Bridgetown sewerage system that it is to be expanded and not the South Coast Plant. The proposed increased treatment capacity of the Bridgetown Plant, contingent on the expansion of the sewerage collection system is indicated in the Conceptual Design Report prepared by Integrated Sustainability. The approved Report is not available, at the time of writing, though a preliminary draft is available.

5.1 Wastewater generation historic analysis

5.1.1 Baseline data

The contract requires the consultant to make a 20 to 30-year projection of treated wastewater going through the Bridgetown and South Coast Sewage Treatment Works. For convenience we assume that the projection horizon is to 2050 i.e., the period 2020 - 2050. Both the Bridgetown and South Coast collection systems are designed as sanitary sewers, meaning that they do not accommodate stormwater, stormwater is handled by the drainage system. The Baseline Report indicated that there was some evidence of stormwater ingress into both the Bridgetown and South Coast sewerage systems but suggested that this was not a regular or significant event and would not have a critical impact on the determination of treatment capacity.

In making the projections of wastewater volumes, data provided by the Barbados Water Authority has been used. There are no records of inflow into the Bridgetown Works and in the case of the South Coast Works, there are inflow measurements from a Parshall Flume. The record of monthly average daily inflows data was provided for the period January 2019 to May 2021.

In the absence of inflow data, the estimations of wastewater flows have been derived from water consumption records of customers connected to the two wastewater collection systems. The assumption is that a portion of the water consumed, typically taken as 80%, will go into the wastewater collection system and enter the treatment works. Monthly consumption data for the years 2017 to 2021 were provided in Excel format, giving the customer number, customer name, account number, address, district, rate schedule (M1 - M6), customer type, parish, service type and start date, and monthly consumption records.

This data did not contain information indicating which treatment works a customer was connected to. The Excel sheets contained both missing and erroneous data. Missing data of interest included no indication of district and/or parish, the account address not matching the customer location. Erroneous data consisted of either incorrect consumption records, due to incorrect meter readings, missing consumption records, the same repeated readings, and dubious fluctuations in consumption between months.

All records were manually inspected in order to address the missing data and errors. Through customer information and inspection of the addresses given, it was possible to assign an account to a district and hence parish. The next step was to assign each account to either the Bridgetown or the South Coast systems. This was done through inspection of the address and district information cross-correlated with information provided on which districts each of the works covered an allocation. The number of connections to each system derived from this inspection were checked with the BWA wastewater division and found to be in good agreement. The information on account number, address, district, rate schedule, customer type, parish and works was exported from Excel into MS Access. This did not include annual monthly consumption data.

Annual monthly consumption data was provided in separate worksheets containing the account number and the monthly consumption. The monthly consumption records were manually inspected to detect and address erroneous records. This mostly meant addressing a negative consumption record followed by an abnormally high consumption record. Once the data had been ‘cleaned’ the Excel worksheet was imported into MS Access. In Access, record tables were linked via account numbers and a query run on account number, rate schedule, works and monthly consumption. The query results table was then exported to Excel for further analysis. The analyses consisted on totalling monthly consumption by rate schedule and works and the producing graphs of these results.

This procedure was carried out for 2017 to 2021 and therefore covered the pre and current Covid-19 pandemic period. The results of the analyses are presented in graphical format and are shown in the figures in the following section.

5.1.2 Results and evaluation of consumption data

Figure 16 shows the comparison between Bridgetown and South Coast sewerage systems consumption. The results have been plotted to the same scale for ease of comparison. The plots give some indication of the problems encountered with the data mentioned above.

For the South Coast, it is obvious that hotel consumption (M3) is the largest category, and the impact of the pandemic is abundantly clear, though it does not totally collapse as properties still have to be maintained. Consumption in the Government and Statutory rate schedules (M4 &M5) make a minor contribution to overall consumption. Residential and commercial consumption (M1 & M2) constitute are similar in magnitude.

For the Bridgetown system, over all consumption is much smaller than that of the South Coast. The residential consumption is lower than the other rate categories. Commercial and Government consumption are both significant, as might be expected given that Bridgetown is predominately a commercial centre and home to many government bodies.

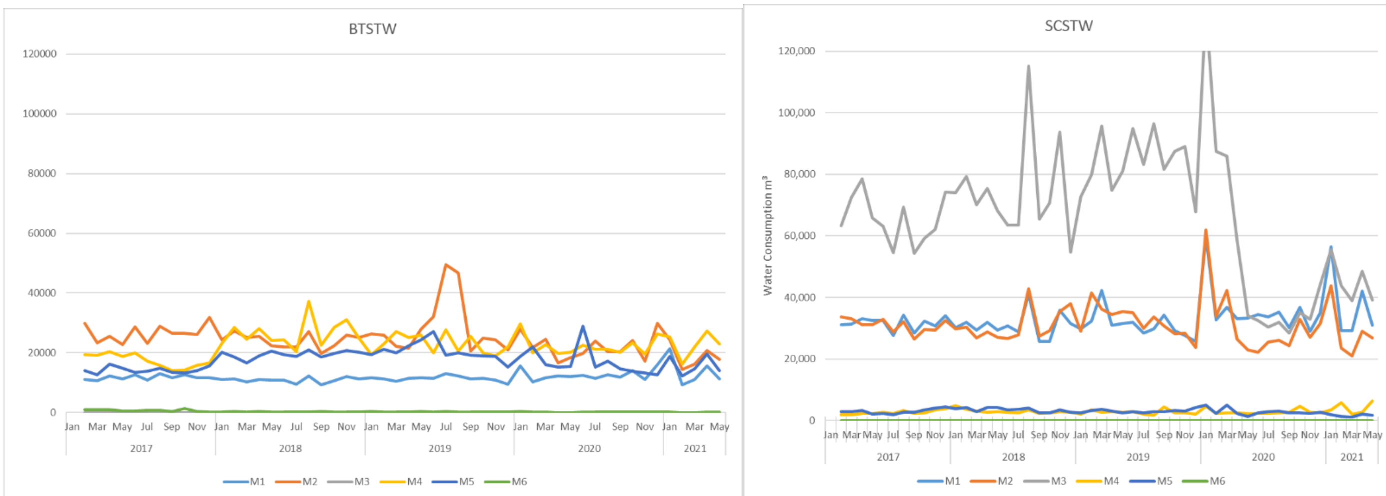


Figure 16: Monthly consumption by rate schedule and year for the Bridgetown and the South Coast Sewerage Systems

The records were further examined to try to determine any trends in consumption over time. This is reflected in the figures below

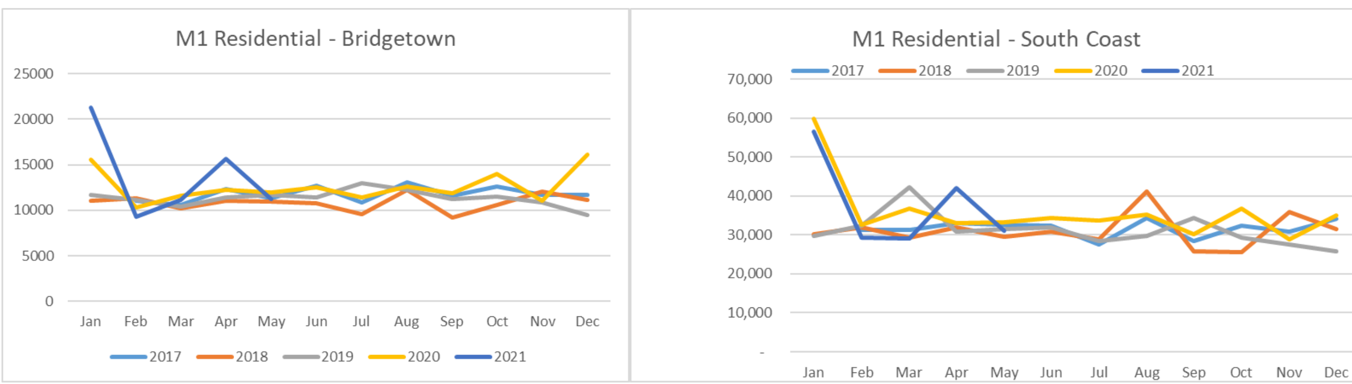


Figure 17: Comparison of Residential Consumption by Year and System

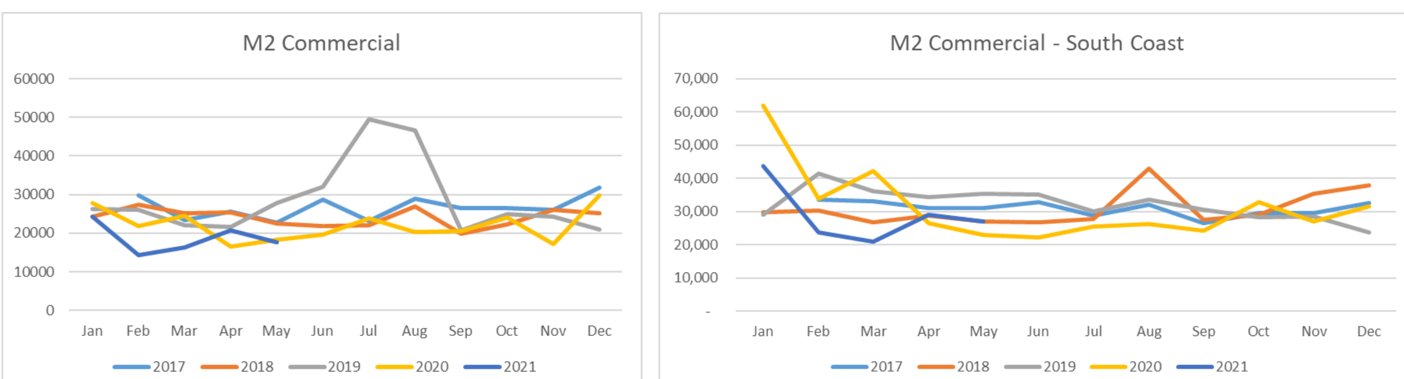


Figure 18: Comparison of Commercial Consumption by Year and System

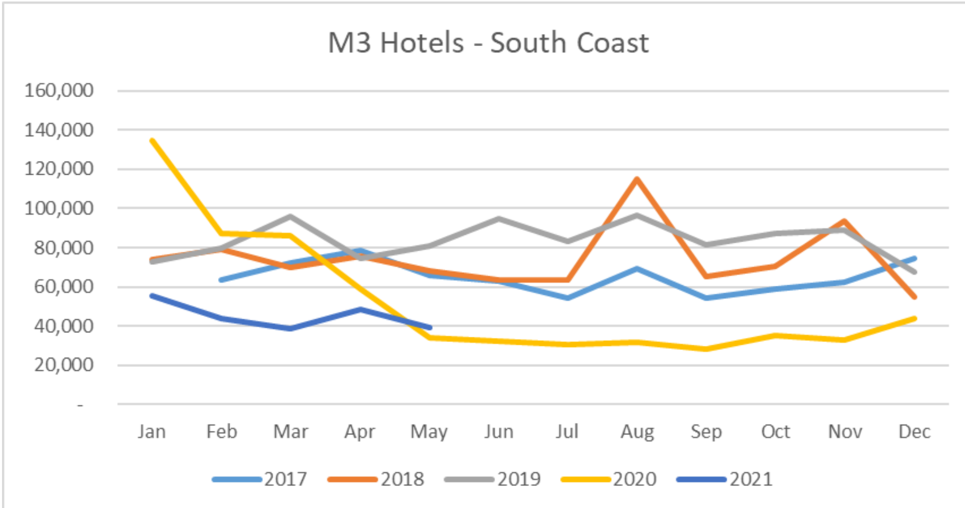
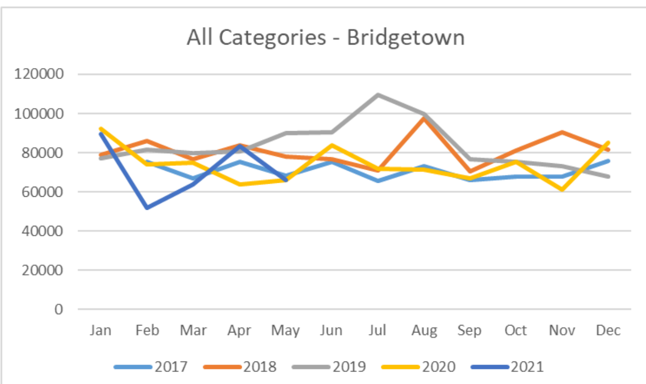


Figure 19: Comparison of Hotel Consumption by Year



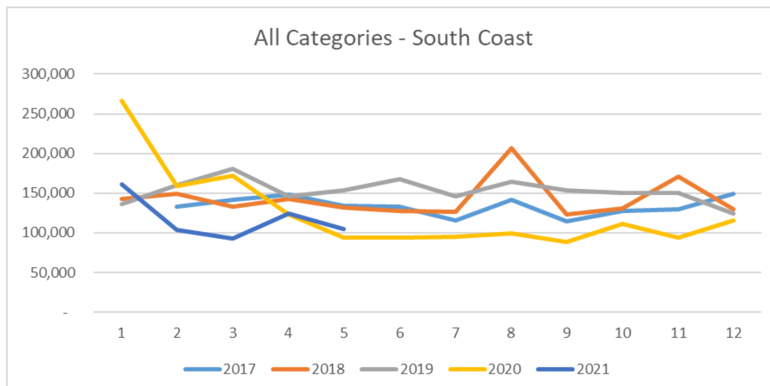


Figure 20: Comparison of Total Consumption by Year and System

Overall and apart from the obvious impact of the pandemic, there are no strong trends in the data. An examination of the spread of monthly average daily consumption data between the Bridgetown and South Coast systems indicated that there is much less fluctuation in the Bridgetown consumption as compared to the South Coast system, see Figure 21. Whether this is a function of the differences in characteristics of the two systems i.e., the South Coast is inherently more variable because of dominance of consumption by hotels, or due to errors in the data cannot be determined but both are thought to play a role.

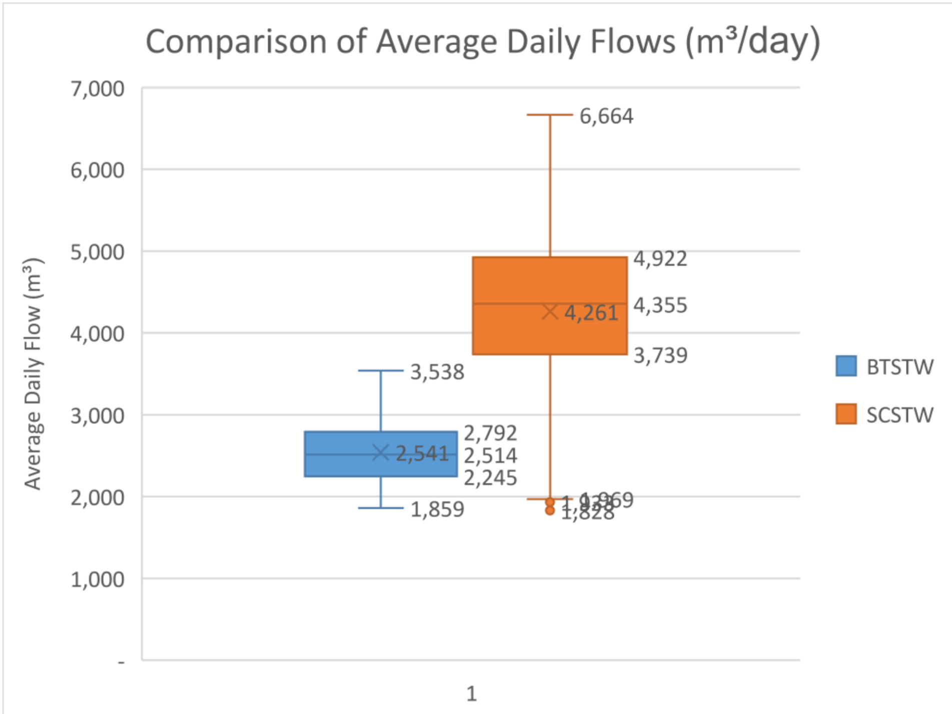


Figure 21: Comparison of Consumption Distribution by System

Further analysis of the data was carried out to determine if any trends could be detected, paying attention to the pre-Covid 19 and post pandemic situations. This is illustrated in Table 6 which does indicate that there is indeed, as expected, an impact on residential – an increase, on commercial – ambiguous, on government and statutory – an increase, and on hotels – a decrease.

Table 6: Comparison of Average Monthly and Average Daily Unit Consumption

BTSTW	Average Monthly Consumption (m³)		Unit Consumption (m³/connection/day)		Active Accounts		Total Accounts	
	2017	2020	2017	2020	2017	2020	2017	2020
M1	11,773	12,591	0.51	0.60	694	685	751	745
M2	26,638	22,050	1.78	1.70	450	427	553	540
M3								
M4	17,380	22,214	11.88	16.72	44	44	60	55
M5	14,183	16,924	11.06	14.90	39	37	49	49
M6	701	58	10.57	1.61	2	2	2	2

SCSTW	Average Monthly Consumption (m³)		Unit Consumption (m³/connection/day)		Active Accounts		Total Accounts	
	2017	2020	2017	2020	2017	2020	2017	2020
M1	31,664	35,815	0.53	0.67	1814	1761	2034	1994
M2	30,990	31,432	2.74	3.03	341	341	402	403
M3	65,155	53,008	28.65	25.98	69	67	73	68
M4	2,649	2,850	7.32	9.45	11	10	11	11
M5	2,975	2,853	7.64	7.41	12	13	14	14
M6								

The analysis of the consumption figures has been used to derive the basic input parameters for the forecast model.

5.2 Projections

The Terms of Reference call for a 30-year projection. The projections will be given for the Bridgetown and South Coast areas separately. The projections are based on the analyses of the consumption data to derive figures for input into the projection model. The basic wastewater projection draws on information regarding future developments which would have an impact on the generation of wastewater flows. The developments range from those abut which there is a good degree of certainty through to more speculative assumptions regarding developments. These are set out in the following sub-sections. At this stage assumptions regarding increases in per person wastewater generation, the impact of climate change and changes in number of connections are not explicitly included. These will be included as scenario options in the wastewater projection model which will be an integral and driving part of the financial model. The potential impacts of these factors are discussed here.

The basic assumptions are that for the Bridgetown area the treatment works will be upgraded and expanded, implying that there is an expectation that there will be more service connections feeding into the works and hence the collection system will be extended. For the South Coast it is stated that although the works will be upgraded there will be no increase in treatment capacity. However, as there may be spare capacity some expansion of the number of connections could be accommodated.

5.2.1 Bridgetown Area

There is a reasonable expectation that connection coverage will be extended to the Chapmans Land/Fontabelle/New Orleans areas bringing in and additional 820 properties. It is assumed that this will occur within the next two years and will include a provision for residential and commercial properties but no other types of property. As these are established residential areas it is assumed that all properties are occupied.

Since the early 2000's there has been proposals to sewer additional areas of Bridgetown as a measure to address deteriorating water quality around the Belle pumping station area. The assumed coverage is taken from the 2004 Stantec Feasibility Study. It is assumed that the coverage will include residential, commercial, government and statutory consumers. The relative phasing of the extended coverage areas is taken as per the 2004 Report. Again it is assumed that as these are established areas, all properties are occupied. The assumption is made that the extension will follow on from the above and that together will be spread over a 5-year period.

The Integrated Sustainability Conceptual Design Report on the Bridgetown Works assumed an extended sewer coverage area and a future served population. We find their calculations to be based on assumptions of served population which are overly optimistic. Therefore, the following approach was adopted.

- The extended sewer coverage of the Bridgetown municipal area is accepted, as shown in the Concept Design Report.
- The population of this area was determined from the 2010 Census. The Enumeration Areas included in the extended area were identified. The recorded 2010 population and number of occupied and unoccupied properties for each of the included Enumeration Areas (EA) was abstracted.
- Household size for each EA was determined.
- Average household consumption was determined from the consumption records of the Bridgetown and South Coast areas. Based on the average household size per capita

consumption was calculated and compared with other reported figures for Barbados. The figures were found to be comparable. Average daily household water consumption was taken as being 0.55 m^3

- Allowance for commercial, government and statutory authority consumption in the extended area has to be included. Two approaches are possible. The first would be to determine an average consumption for each rate schedule category (i.e. commercial, hotel, government, statutory – the port is not included). To apply this would require knowledge or assumptions of the expected number of connections. The second is to assume that they can be taken as a percentage of the residential consumption – making the link between population and demand for services. The second approach was adopted. Then it is to be determined what those percentages should be. For this the percentage breakdown for both Bridgetown and the South Coast were examined. The Bridgetown breakdown was not used as it contains a high presence of commercial and non-residential consumption. The South Coast was considered more representative with respect to government and statutory consumption but not for commercial. As a predominantly tourist area with a significant number of hotels it was assumed that commercial consumption would be over-represented as compared to more residential areas. For the extended Bridgetown area hotel consumption is ignored.
- Based on the above the following percentages were: residential 60%, commercial 20%, government and statutory agencies 10% respectively. These were translated into a percentage of the residential consumption for calculation purposes.
- The analysis of numbers of households and numbers of persons per household is based on figures taken from the 2010 population census. An established trend for the parish of St Michael has been a long term decline in residential population as people relocate to surrounding parishes such as Christ Church, St George and St Philip. A conservative assumption would be to ignore this and assume that the 2020 population of the area is unchanged. The alternative would be to factor in a population decline based on historical records. However, in the absence of data on this trend, the status quo assumption is accepted. Future trajectories of population and hence water and wastewater generation are handled through the use of different scenario assumptions.

In addition to these developments, there has been much discussion around the redevelopment of the Bridgetown Central Business District (CBD) and surrounding areas. The Physical Development Plan (2017) includes a Community Development Plan for Bridgetown, but this only provides policy guidance. The following assumptions are made concerning potential future developments.

- The Hyatt Ziva development n Bay Street will be coming on stream within the next two years the. From figures provided by the developer they expect a water consumption of approximately 1,000 m^3/day.
- Waterfront - Cavans Lane Redevelopment - the site has been acquired by a developer for redevelopment. Information indicates that a 250-room hotel, condominiums, and retail space is to be developed. Information on this is taken from the address by Senator Walcott during the Appropriation Bill March 2021. Operational 2025
- Bridge House and Carlisle House Redevelopments, as mentioned by Senator Walcott, to include residential and commercial space.
- Bridgetown CBD Transformation - the 2017 Bridgetown Community Plan puts forward guidance for future development of the area. Most of the focus is on supporting

commercial activity and creating a better urban environment. There have been suggestions to increase residents through developing apartments. This possibility has been included.

The inclusion of these developments is to be handled through the use of scenario choices with consumption and hence wastewater generation rates being based on the analysis of historic consumption records.

5.2.2 South Coast area

The South Coast Sewage Treatment Works receives wastewater from the coastal strip between Jemmotts Lane/Lower Collymore Rock and Oistens. This is an area where there is a high concentration of hotels, and businesses which support tourism, this can be seen from the fact that hotels constitute over 50% of total consumption, whilst residential and commercial constitute approximately 20% each. The baseline assumption for the future is that there is no increase in treatment capacity and this is taken as implying no increase in connection coverage.

- With respect to other possible developments the following is assumed; that under a scenario whereby the Carlisle Bay Beach & Needhams Point Precincts is developed, an additional 2,000 m^3/day would be consumed in the M3 – hotels rate schedule and that there would be a knock-on effect on commercial consumption amounting to 25% of the hotel demand. The figure of 25% is based on the ratio between hotel and commercial consumption in the South Coast area. If and when this additional volume would be factored in will depend on choice of scenario. No increase in residential consumption is included.
- Analysis of the consumption records for the South Coast Sewage Treatment Plant taken together with records of inflow data suggest that there is spare treatment capacity. Furthermore, it appears that the original number of planned connections was 3,000 whilst at present the number is approximately 2,000. Again suggesting that there is spare treatment capacity and perhaps additional connections could be made to the existing collection system. An option to be included is for there to be an expansion of the number of connections over time to take the projected inflow up to the average daily treatment capacity of 9,000 m^3. It is assumed that the additional daily volume would made up of a mix of residential, and non-residential flows. To determine the mix, the same breakdown of consumption as for the extended Bridgetown coverage is used.
- There is a further option that has been put forward which entails coupling the South Coast Works to the Coverley Village development and providing wastewater collection and treatment for the area surrounding Coverley Village. The apparent intention behind this is to increase the volume of wastewater to be able to provide treated water to the Gibbons Bog area. At this stage this option is regarded as purely speculative and with no details it is not included in the projection options.

5.2.3 Bridgetown and South Coast Projections

For illustrative purposes only the following two figures illustrate a possible future scenario for wastewater generation and treatment. These will be superseded by the actual financial model.

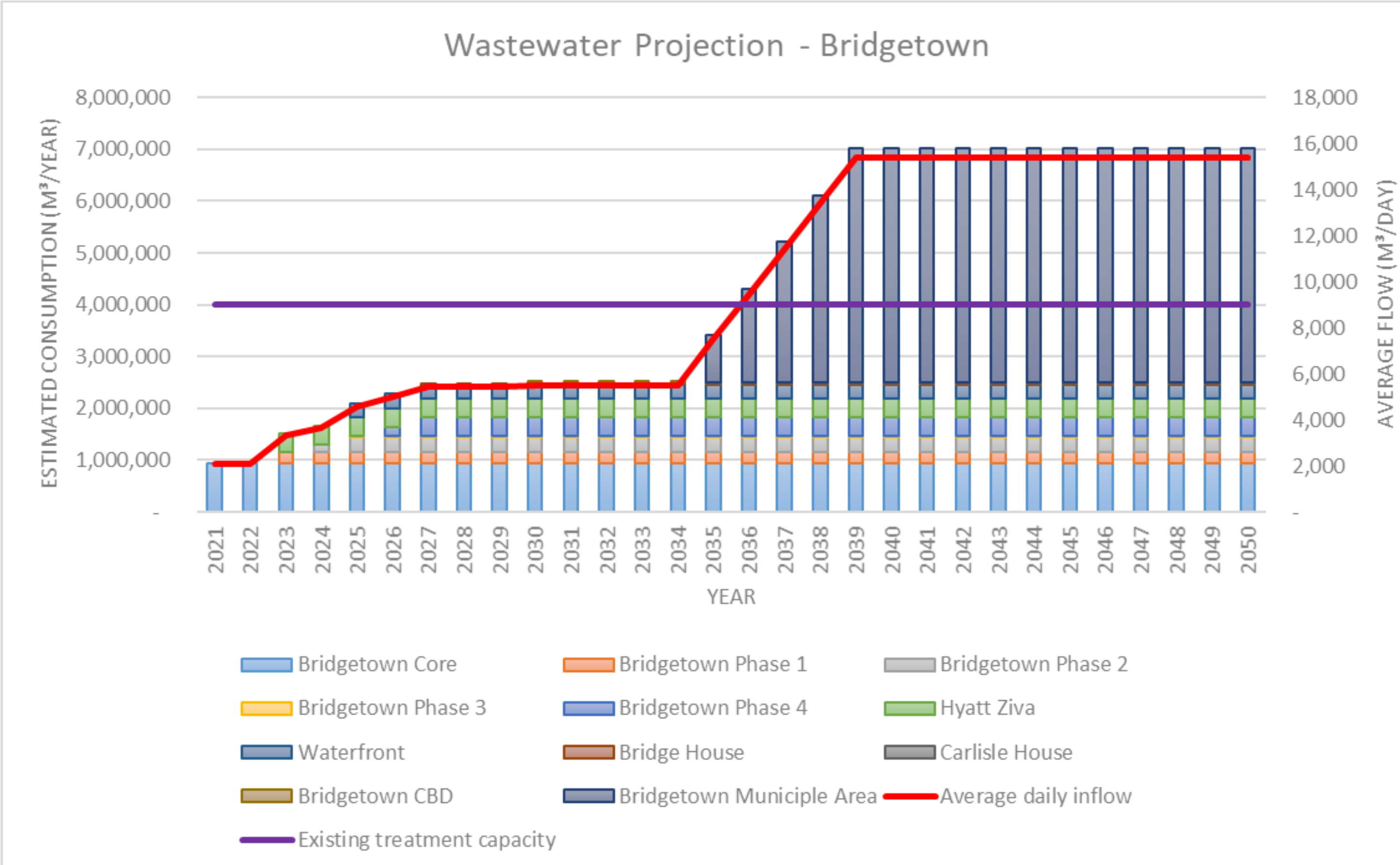


Figure 22: Wastewater Projection for Bridgetown

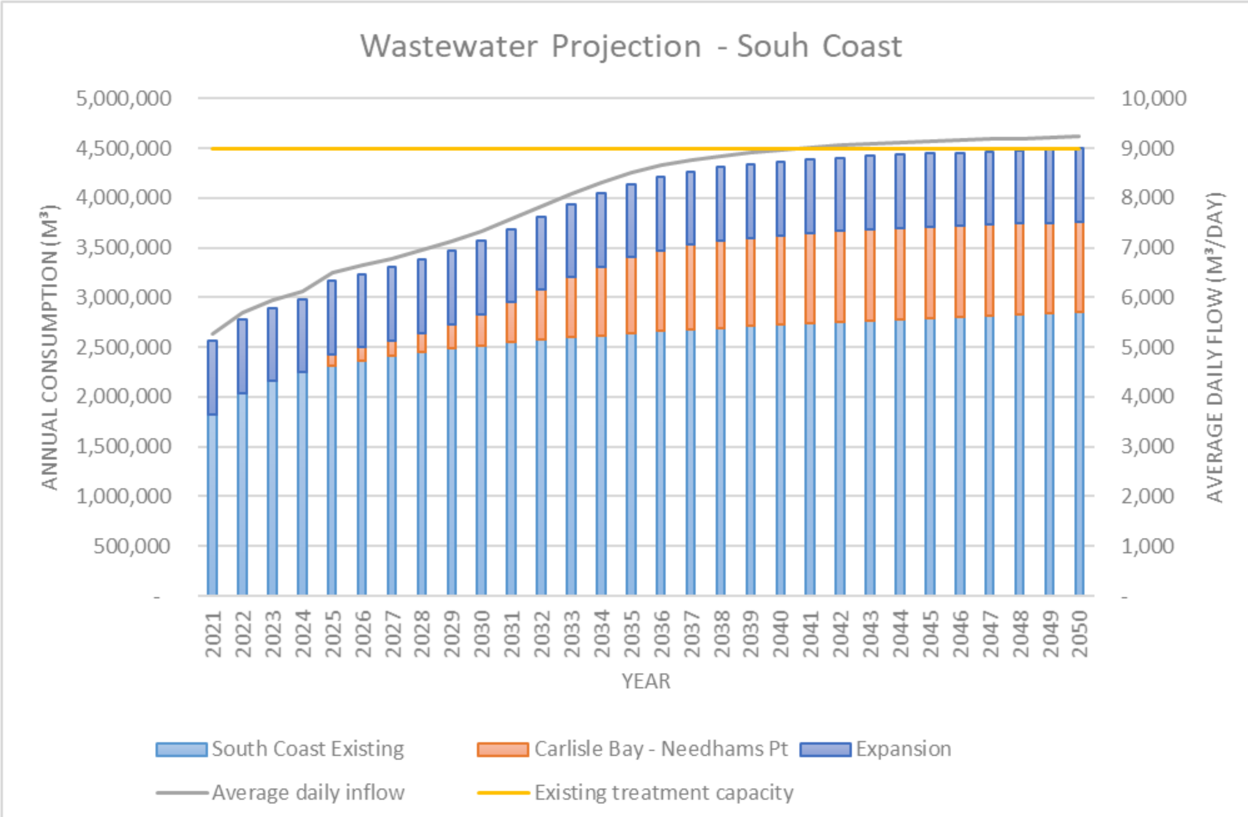


Figure 23: Wastewater Projections - South Coast

5.3 Influencing factors

The variables that would have an influence on the projections and are to be built into the projection scenarios include:

5.3.1 Demographic changes

As noted above, there has been an observed trend in St Michael of population decline as people relocate to surrounding parishes. It can either be assumed that this trend continues into the future under some scenarios, that there is no further decline in population or that the decline is reversed and population increases. The implications are assumed to be as follows:

1. Population decline – the number of connections to the extended system declines. A percentage rate or straight-line decline could be applied. It is assumed that the existing Bridgetown areas are unaffected.
2. No change – the number of connections projected remain the same.
3. Population increase – if the collection coverage is extended then it could accept new connections. An assumed population increase rate and assumption of household size (number of persons per household) can be used. This is applied to the Bridgetown systems.

In contrast the population of Christ Church has increased. Most of the increase has come about in areas not served by the South Coast system. So for population increase to have an effect it would imply the development of vacant lots within the existing covered area or the connection of additional, occupied lots. Whilst this would happen, the impact is considered to be minor as the area served is already densely settled.

The other demographic change is the number of persons per household. Again figures suggest the household size is declining. This could be factored in but it is considered that there would have little effect in the already served and about-to-be-served areas of Bridgetown. It is argued that the trend would more likely affect the to-be-serviced areas of Bridgetown and possibly the South Coast residential consumption. An assumption of no effective change would be a conservative one.

5.3.2 Technological change

It has been observed that per person water consumption tends to decrease over time. This effect is ascribed to changes in fixtures and fitting which have become more efficient, using less water to produce the same result. For example, the volumes of water used by toilets has decreased over time. It is highly likely that this trend will continue and be manifest over a longer period of time as households change their appliances. It is proposed that this effect be factored in, although it could be affected by economic circumstances. This can be handled through the choice of scenario.

5.3.3 Climate change

5.3.3.1 Impact on Demand

As noted in section 3, the effect of weather and climate change on residential water consumption in the Caribbean has not been studied. There is literature which suggests that as temperatures increase so does water consumption, however, the magnitude of the impact varies depending on circumstances and is influenced by changes in precipitation. This is particularly the case where a proportion of household consumption is used for gardening and similar uses. Thus, increases in consumption may not result in increases in wastewater generation. The available literature appears to suggest that a 1ºC change in temperature results in between 3 – 7% increase in water consumption.

For the purposes of projection, a 5% increase in total water consumption is used for a 1ºC increase in temperature. It is further assumed that this does increase the volume of wastewater generated. This is taken as affecting residential and hotel water consumption and hence wastewater generation.

The degree to which temperatures might increase depends on which climate scenario is selected. Projections of temperature changes by RCP are available from the World Bank Climate Portal for maximum, minimum and average temperatures using median values from the ensemble results. For the purpose of calculations, the annual increase in average temperature is used. The following table set out the decadal temperature increases to be used.

Table 7: Increase in Average Daily Temperatures (°C)

Climate Scenario	Year		
	2030	2040	2050
RCP 2.6	+0.23	+0.35	+0.43
RCP 4.5	+0.19	+0.40	+0.74
RCP 6.0	+0.27	+0.26	+0.76
RCP 8.5	+0.41	+0.61	+0.86

5.3.3.2 Impact on Supply

As climate change is assumed to have a negative impact on water availability it could provide the impetus for the introduction of measures to curb consumption such as pricing, induce behavioural change and promote technological change. All with the aim of reducing consumption. Technological change is already factored in. For the purposes of these projections the potential impact of pricing and of behavioural change are not factored in.

The studies available indicate that climate change will reduce the safe yield of aquifers. The extent of the reduction would be dependent on climate scenario, with the more severe scenarios e.g. RCP 8.5 having a greater impact. At present abstraction from the aquifers is approaching their sustainable yield; abstraction is around 80% of the safe yield meaning that increases in demand would push abstraction to equal or exceed the safe yield – which would be unsustainable. This situation is being offset by increases in the current desalination capacity, which provides at present approximately 20% of the consumption demand.

If demand for water increases and there is a decrease in aquifer safe yield, all other things being equal, this would result in constrained demand. In other words, demand would be constrained to be equal to the available supply. The magnitude of the difference between demand and availability would depend on the degree to which climate change might decrease the safe yields – that is on the climate scenario.

The unconstrained consumptive demand for the Bridgetown and South Coast areas can be calculated according to the Scenarios set out in Section 5.4. For the rest of the country assumptions for the growth of demand can be made, also in line with scenarios. The level of real water losses would have to be included in order to arrive at the aggregate consumption. For calculation purposes it would be assumed that no additional sources of supply are factored in. Hence, only two sources are considered, aquifer safe yield – affected by climate change and, desalination – assumed to be held constant at $15Mm^3$/year capacity. However, there are a number of interventions on-going that are addressing water losses, and these should be factored in as they will reduce the level of abstraction required to meet demand. The following changes is estimated safe aquifer yields are used, see Section 3.6 for references. Median changes in aridity are derived from https://climateinformation.org/create-report/ using the Data Access Platform. Aridity is used as it represents the ratio of the average annual precipitation and the potential evapotranspiration and is taken as an indication of the potential effect of climate change on recharge potential; the higher the aridity index the less potential aquifer recharge.

Table 8: Aquifer Safe Yields

Climate Scenario	Median Change in Aridity 2050	Estimate Average Annual Aquifer Safe Yield 2050
Baseline	0%	65.7 Mm^3
RCP 2.6	17.15%	No data
RCP 4.5	21.42%	$31Mm^3$
RCP 6.0	No data	No data
RCP 8.5	24.96%	$29Mm^3$

5.3.4 Economic influences

Economic influences are considered to have the most significant impacts on water consumption and wastewater generation. In order to accommodate this a scenario approach is proposed. The scenarios may also have an effect on the other factors discussed above. The proposed scenarios are discussed in the next section.

5.3.5 Wastewater generation

Not all water consumed becomes wastewater, only water that goes through an appliance, fixture or fitting that is connected to wastewater collection system contributes to the volume passing through the sewage treatment works. So water used by a household for gardening purposes, outdoor use or the like would not contribute. To take this into consideration, it is assumed that 80% of water consumption becomes wastewater and enters the collection system. This figure has been suggested by BWA persons. It could be varied though to test the impact; with a lower value of 70%.

The assumption is made that as these are sanitary sewers no stormwater enters the system. This may not be the case as stormwater could enter through unsealed manholes. However, given that these would be occasional incidents it is considered that they can be ignored.

The other source of additional water in the collection system is groundwater that infiltrates through cracked and damaged pipes. At present there is no evidence one way of the other that this is a problem. The major breakdown of the South Coast collection system did highlight how this could be a problem. Again, this is ignored.

5.4 Scenarios

Four scenarios are proposed to examine the sensitivity of the financial outcomes to different assumptions regarding wastewater generation. The scenarios are based on different assumptions regarding socio-economic developments and are outline below. In addition, the wastewater projection model will include the ability to change other variables, discussed above and to choose which developments are included.

5.4.1 Scenario 1: Economic decline

In this scenario the economy is assumed to decline, all of the developments discussed above do not happen and hotel and commercial activity declines with a knock-on effect on residential consumption. There is a decline in the population of St Michael. The impact on government and statutory bodies is less certain and a working assumption is that it has a neutral effect i.e. their levels of water consumption are unchanged.

5.4.2 Scenario 2: No growth

Residential and non-residential consumption does not change from present levels, and no population growth in St Michael. The proposed extensions for Bridgetown are implemented but not the full extended collection coverage. The Hyatt Ziva development goes ahead. For the South Coast, no further developments go ahead.

5.4.3 Scenario 3: Business as usual

This is the same as Scenario 2 but includes the extension of sewer collection system in Bridgetown and there are increases in the population of St Michael.

5.4.4 Scenario 4: Growth and Expansion

All of the developments noted come to fruition including Bridgetown extension and CBD development, hotel developments along the Carlisle Bay to Needhams Point occur and the South Coast system is fully utilised. Coverley Village speculation is not included.

6. Treated water reuse

6.1 Introduction

At present all treated wastewater from the Bridgetown and South Coast Sewage Treatment Plants is disposed of into the marine environment via sea outfalls. It is the Government's policy that in future this practice should cease, and that wastewater should be put to some form of beneficial use. In order to do this, the quality of the wastewater has to be improved to ensure that it would be in compliance with water quality, and health and hygiene standards. This means it would have to be treated to tertiary level. Hence the rationale for the upgrading of both Sewage Treatment Plants.

During and following the ash fall from the St Vincent La Soufriere volcano, wastewater from the Bridgetown Plant was tankered to the wastewater treatment facility at Coverley Village for treatment through the facility. The treated water was then used for non-potable purposes to aid the clean-up operations, for example at the Grantley Adams International Airport. This has highlighted the potential for wastewater reuse. Furthermore, the BWA is purchasing 6 non-potable water tankers to aid the distribution of treated wastewater. Details of the potential clients, volumes and associated costs have not been provided.

The potential uses of treated wastewater are shown in Table 9, along with how frequently the use might be and the implications in terms of the associated infrastructure required to facilitate reuse. The water quality requirements also vary and need to match potential usage.

Table 9: Potential uses of treated wastewater

#	Use category	Frequency of use	Infrastructure requirements
1	Direct potable reuse	Constant	Balancing storage and transmission pipelines.
2	Industrial use	Constant	Transmission pipeline
3	Cooling water	Constant	Transmission pipeline
4	Forestation	Occasional supplementary	Tanker services with on-site storage and distribution
5	Landscaping	Supplementary, mostly dry season to cover water deficits	1. Tanker services with on-site storage and distribution 2. Balancing storage and transmission pipeline in the case of large users such as golf courses
6	Municipal use e.g. street cleaning, dust suppression, etc.	Occasional	Tanker service
7	Managed aquifer recharge – indirect reuse	Constant	Balancing storage, transmission pipelines and injection well-field.
8	Non-potable use e.g. toilet flushing	Constant	Dual reticulation system alongside potable water distribution
9	Agriculture 1. Crop irrigation 2. Pasturage 3. Orchards	Supplementary, mostly dry season to cover water deficits	Balancing storage, transmission and distribution pipelines to point of use. On-site infrastructure would also be required; storage and distribution infrastructure.

10	Agriculture 1. Non-irrigated	Occasional supplementary during periods of drought	Tanker services with on-site storage

Use categories 1 and 8 are not considered. Use for categories 4, 5, 6 and 10 could be supported, as indicated, through the provision of a tanker service. The level of demand though would be uncertain and would fluctuate. As a service it could be provided either by the BWA or by private contractors. If provided by a private contractor, BWA would sell the treated water to the contractor and they would roll that into their service charge. If provided by the BWA then the cost should include the cost of treated water plus the cost of delivery. The suggestion that only the marginal cost of delivery might be charged is clearly a policy decision to be made by the BWA.

Options for using treated water for golf courses, use category 5, have been investigated as part of the feasibility studies for the West Coast Sewerage Master Plan (Stanley International & Klohn-Crippen, 1997) and the Water Augmentation Concept Report (CDM, 2006). The 1997 report was premised on the sewering of the West Coast as an addition to the Bridgetown (Emmerton) Sewage Treatment Plant; demand for treated wastewater was estimated to be 6,400 m^3/day for the 3 golf courses. The 2006 report expanded the potential number of customers for treated wastewater, see Table 10 – SC indicates South Coast. It should be noted that there have been changes since 2006 and some of the information is out of date.

Table 10: Potential Treated Wastewater Reuse Customers (CDM, 2006)

Potential reuse customer	Need for treated water	Estimated maximum demand (m^3/day)
Barbados Light & Power Spring Garden Plant	Cooling tower make-up	3,600
Sandy Lane Golf Course	Irrigation	4,730
Sugar Hill Golf Course	Irrigation	1,910
Apes Hill Golf Course	Irrigation	1,910
Black Bess Quarry	Irrigation	1,910
Royal Westmoreland Golf Course	Irrigation	1,910
Rockley Beach Golf Course	Irrigation (SC)	950
Banks Brewery	Machinery cooling (SC)	770
Pine Hill Dairy	Machinery cooling	1,590
Barbados Bottling Company	Machinery cooling (SC)	770
BADMC Agricultural Lands-Christ Church	Irrigation (SC)	4,500
SC Total		6,990
Total		**24,550**

The Terms of Reference specify that the potential uses for treated wastewater to be considered are *“irrigation ‘brown’ and hotel ‘grey’ water”*.

As indicated in the Inception Report, hotel grey water is not considered. The reason is that supplying grey water back to hotels along the South Coast would require the installation of a new distribution network along a heavily built-up area. This would serve the 73 hotels along the strip many of which have limited landscaping requirements. It is not considered financially viable to construct and operate such a system. For these reasons this option is disregarded.

6.2 Agricultural Use

6.2.1 Available irrigable land

The potential demand for the reuse of treated depends on how much land could potentially be irrigated and how much water would be needed for irrigation. Information on how much land could be irrigated has been gathered from three sources; firstly, from the BADMC, secondly, from the Physical Development Plan indicating the Integrated Rural Development Project areas, the agricultural lands classification and the soil protection overlay, thirdly, form information provided by the Department of Lands and Survey. This has led to a focus on the southern part of Barbados – an area running from The Belle in St Michael parish through to St Philip parish; the St George's Valley. It is clear the inspection that there are large areas of potentially irrigable land, some of which is already irrigated, though the vast majority rely to a great extent on rain fed agriculture.

Attempts were made to gather information on farming activities from the Ministry of Agriculture and Food Security, through the Chief Agricultural Officer. Unfortunately, the Ministry's information is out of date and incomplete and was therefore not able to provide any information regarding farms, farmers, areas under cultivation or crops grown.

The information provided by BADMC on irrigated lands is shown in Table 11.

Table 11: Areas of IRDP Lands

Integrated Rural Development Project (IRDP) Districts	Area (Ha)
Private lands	
Belle, St. Michael	27
Salters, St. Michael	26
Haggatt Hall, St. Michael	9
Wilcox, Christ Church	30
Silver Hill, Christ Church	7
Fairview/St. Patricks, Christ Church	11
Gibbons Boggs, Christ Church	52
Pegwell Boggs, Christ Church	8
Kirtons/Heddings, St. Philip	56
Ruby, St. Philip	40
Sandford, St. Philip	65
Union, St. Philip	13
Marchfield, St. Philip	11
TOTAL	**355**
Land Lease Districts	
Pine Basin	20
River Plantation	16
TOTAL	**36**

GRAND TOTAL	**391**

In addition to these lands other potential land areas that have been identified, the areas of which have been calculated approximately. The choice of area has been guided by limiting the elevation of the lands and thus they represent a subset of all the potentially suitable lands in the southern part of Barbados.

Table 12: Additional potentially irrigable lands

Lands	Area (Ha)
Jackmans, Neils, Waterford & Codrington	370
Constant - Hanneys	1100
Hampton – Padmore/Harrow	900
Total	**2,370**

In total it is assumed that in the southern part of Barbados at least 2,700 hectares of land could be considered for irrigation. The potential demand for irrigation water is calculated assuming how much irrigation water would be required per hectare. This amount varies by crop. The Ministry of Agriculture and Food Security in the "Cost Benefit Analysis for the Provision of Reclaimed Water for Irrigation Purposes" (Agricultural Planning Unit, 2021), assumed an application of 50 m^3/hectare. This can be compared with a figure of 35 m^3/hectare for a golf course in the 1997 Stanley-Klohn Crippen Report. Using the lower figure, the potential daily demand would therefore be 94,500 m^3/day (118,500 m^3/day at the higher figure). This assumes that all the land is irrigated at the same time and that all the potential land is irrigated – which clearly would not be the case.

6.2.2 Acceptability

The potential reuse of treated wastewater in Barbados has been recognised for several decades. A related aspect is how would the potential reuse be viewed. There are three constituencies whose views are relevant. One constituency is that of the authorities which would have regulatory oversight, principal among these would be the Environmental Protection Department (EPD) and the other would be the Ministry of Agriculture and Food Security. Another constituency would be farmers who would be the potential beneficiaries, and the third would be the consumers of the crops produced.

The EPD have developed water reuse guidelines and the Ministry of Agriculture and Food Security have stipulated water quality conditions governing the potential use of treated wastewater. Hence, the regulatory guidelines are in place. A regulatory regime to ensure compliance would have to be put in place. All produce should meet national phytosanitary requirements, set down by the Ministry. So, from a regulatory standpoint there would be no acceptability barriers.

In order to determine acceptability to farmers, several discussions have been held. These have included discussions and meetings with;

- Ministry of Agriculture and Food Security – Deputy Chief Agricultural Officer
- Barbados Agricultural Development and Marketing Corporation – Manager Agricultural Services Division
- Large scale commercial farmers,
- Barbados Agricultural Society – General Secretary

- Farmers discussion forum attended by 12 farmers representing vegetable farmers, pig and poultry farmers, dairy and small ruminant farmers.

In addition to these discussion, previous studies have been consulted.

The overwhelming consensus coming out of the discussions and from the studies is that farmers are supportive of the use of treated wastewater. Farmers have been experiencing the impact of prolonged dry periods, which they say are happening more frequently and they are losing income. So having access to water would be a great relief to them. Some cited the benefit of the nutrients in the wastewater. The main concerns expressed can be summarised;

- Farmers need an assured, consistent and regular supply of water,
- Water quality must be acceptable to regulatory authorities,
- Water quality needs to be consistent,
- Cost of water must be competitive and allow farmers to make a reasonable living,
- Produce that has had treated water must be acceptable to consumers.

Farmers expressed some concern over whether or not this was just another paper exercise that in the end would not result in any development.

It was also pointed out that there are plans to irrigate 31 hectares and have 9 hectares for grazing in the Lears Urban Land Lease Project available to communal and subsistence farmers, developed in conjunction with the private sector. This could benefit from using treated wastewater.

Overall, farmers have no problem in principle in using treated wastewater, their issues are of a practical nature around the management of its provision.

The third group, customers, have not been directly engaged with. The literature suggests (Jimenez & Asano, 2008) that developing consumer confidence is very important and should precede any actual use interventions. In one instance cited, it took almost 20 years of planning before an agricultural reuse project was fully operational (Jimenez & Asano, 2008 p. 346). A limited survey of respondants across Barbados (~60 persons) indicated the following when asked about the use of treated wastewater for agriculture:

- 95% indicated that they were in favour of making treated water available for agriculture and farming,
- 89% were in favour of watering crops on farms with treated wastewater.

This very limited information provides some indication that consumers may be receptive to the use of treated wastewater on crops but it is also clear that much would still have to be done to gain public acceptance.

6.3 Volume available

6.3.1 Agricultural use

From the analysis of wastewater flows presented in Section 5.2 the existing flows of wastewater into the two sewage treatment plants are given below. The figures are based on the following assumptions. For Bridgetown, it is assumed for ‘current’ volumes that the Hyatt Ziva and Cavans Lane developments have come on stream. The available volumes are based on assuming that a final stage treatment of Reverse Osmosis will be installed and that this would reduce production volumes by 10%. For the future, all developments identified in Section 5 are implemented, this is an upper bound, optimistic assumption, and the 10% reduction is applied.

Table 13: Available Reuse Volumes

	Current m^3/day	Available for Reuse m^3/day	Future m^3/day	Available for Reuse m^3/day
Bridgetown	4,600	4,140	15,360	13,800
South Coast	4,500	4,010	9,000	8,100
Total	**9,100**	**8,150**	**24,360**	**21,900**

The implication of these figures is that an area of at least 230 Hectares could be irrigated if both flows were utilised, rising to 625 Hectares in the future. In other words, the area of land that could be irrigated is governed by the available volume of water. The question is where would the water go. The AECOM Feasibility Report (AECOM, 2020) considered three scenarios:

1. Unrestricted agricultural food crop irrigation at River Plantation, Sandford/Mapps, and Golden Grove, areas in St. Philip
2. Unrestricted agricultural food crop irrigation at Gibbons Boggs, Fairy Valley and Fairview areas,
3. Unrestricted agricultural food crop irrigation at St. George Valley.

Scenario 1 was recommended (AECOM, 2020 p. 53), and the flow available for irrigation is given as 5,100 m^3/day (AECOM, 2020 p. 61 & 63).

The Ministry of Agriculture and Food Security's Feasibility Report (Agricultural Planning Unit, 2021) took the above recommendation and consider four different use options, see Table 14. Scenario X1 was the preferred option though X3 was considered to be viable.

Table 14: Scenarios for the use of reclaimed water

Scenarios	Description
X1	Produces 8,100 m^3/day of reclaimed water meeting the Total Dissolved Solids (TDS) limit of 450 mg/l and with a conveyance pipeline to River Plantation
X3	Reduces the capacity of the Ultrafiltration/Reverse Osmosis (UF/RO) by 50% and has the capacity to produce 4,050 m^3/day (at the 450 mg/l TDS limit) and sends that water to River Plantation.
Y1	Relaxes the TDS limit and therefore removes the need for the UF/RO stage and sends reclaimed water with the background TDS to River.
Z1	No agricultural reuse and sends reclaimed water (with no UF/RO stage). Proposes only to recharge the Christ Church aquifer and the conveyance pipeline to River is also eliminated.

What is not clear though is where a figure of 8,100 m^3/day of reclaimed water, subsequently used for calculation, came from. The Ministry's Feasibility Report indicated that the total available area available for irrigation was 150 hectares and that a flow of 8,100 m^3/day could support 191 hectares.

Using the existing projected flow from the South Coast Works of 4,010 m^3/day it would be possible to support approximately half the area indicated in the Ministry's report, which is equivalent to their scenario X3. Taking as a given that there is less water available for irrigation it is suggested that Scenario 2 - the Gibbons Bog, Fairy Valley and Fair View areas be reconsidered as an option. The available volume of treated/reclaimed wastewater would be sufficient to irrigate the area available.

The flows from the Bridgetown Works could support irrigation of a similarly size area i.e. ~ 90-100 hectares. The potential areas considered for the usage have been:

- Transferring the water via a 27 km pipeline to the Spring Hall Land Lease Project in St Lucy (proposed by the MAFS),
- Transferring the water via an 8 km pipeline to the Jackmans, Neils, Waterford & Codrington area (proposed by the MAFS).

The first option is not considered on cost grounds, as it would be significantly more expensive to build and operate than the second option. There is sufficient land area available, see Table 12.

Subsequent to this report being completed, at the request of the Climate Change Centre and the BWA a Cost-Benefit Analysis on four options for the use of treated wastewater from the Bridgetown Plant were investigated. The results of this will form part of a separate report.

6.3.2 Other uses

As indicated in Table 9 there are potential uses for the treated wastewater other than those discussed in Section 6.3.1. Some of the uses could be provided through non-potable tanker services – which the BWA has some of the infrastructure for, whilst others would require similar infrastructure as for agricultural usage. As per Table 9, uses #5 (Landscaping) and #6 (Municipal) could be provided by non-potable tanker services though the volumes are likely to be low and restricted to the capacity of the tanker fleet available. Uses #2 (Industrial), #3 (Cooling), #5 (Landscaping golf courses) and #7 (Managed aquifer recharge) would all require infrastructure.

The Water Augmentation Project considered various use options for treated wastewater, including options for using the South Coast system. The potential uses are identified in Table 10, noting that Banks Brewery has since relocated to the South Coast and could therefore be included. Pine Hill if considered for inclusion would have to be serviced by a separate pipeline system which could also serve the Rockley golf course. The other potential uses could be accommodated from a single pipeline system.

Managed aquifer recharge is included as an option within the schemes to supply treated/reclaimed water to either the River Plantation or Gibbons Bog option which could incorporate supply to the users identified in Table 10, namely; Banks Brewery, Barbados Bottling Company, Rockley and Barbados Golf Courses and the BADMC lands. The reason being that it is that provision would have to be made for handling the treated wastewater that would be surplus to the requirements of potential users. In the case of treated water from the Bridgetown plant, in the Conceptual Design Report (Sustainability, 2021) proposes indirect reuse;

> *The Spring Garden BWRO desalination plant in Bridgetown could potentially be a convenient location to return reclaimed water from the BSTP to the ground in a manner*

that would increase the availability of potable water supplies. The reclaimed water from the BSTP could be piped or trucked and discharged to the ground in vicinity of the Spring Garden BWRO desalination plant groundwater intake, thereby increasing the availability of groundwater in the area. Another consideration could be to treat the wastewater using RO at the BSTP and then blend it with the groundwater that is extracted for treatment at the Spring Garden BWRO desalination water treatment plant.

6.4 Challenges

The challenges foreseen in regard to the reuse of treated wastewater are as follows;

- For irrigated agricultural use, farmers would have to be assured of a reliable supply and of consumer acceptance of their produce,
- Demand for treated wastewater is likely to exceed available supply,
- There would have to be confidence that potential non-agricultural users of treated water would signed up to accept the water,
- Potential consumers of treated wastewater would be able to put in place their own infrastructure to accept the it,

6.5 Summary of options

Based on the information presented in the previous sections the following are the options considered for the reuse of treated/reclaimed wastewater.

Table 15: Summary of Reuse Options

Option	Description	Estimated volume (m^3/day)
A	South Coast STP to River Plantation: As per scenario X3 increasing to scenario X1 as wastewater flows increase. Includes provision for MAR	Initial: 4,010 Final: 8,100
B	South Coast STP to Gibbons Bog: Industrial, recreational and agricultural and includes provision for MAR	Initial: 2,800 Final: 8,100
C	Bridgetown STP to Codrington, Waterford, Neils & Jackson and includes provision for MAR	Initial: 4,140 Final: 13,800
D	Bridgetown STP to Spring Garden BWRO Desalination Plant	Initial: 4,140 Final: 13,800
E	Tanker Service	400

7. Beneficial by-products

7.1 Introduction

The Conceptual Design Report (Integrated Sustainability Consultants Ltd, 2021) for the Bridgetown Plant identifies the possible beneficial by-products of wastewater treatment, whilst the South Coast Water Reclamation Pre-feasibility Report (AECOM, 2020) does not say anything about by-products other than reclaimed water. That said it can be assumed that similar reasoning would apply to both plants. The type, amount and quality of beneficial by-products will be a function of the volume and composition of the incoming wastewater as well as the technology to be used to treat the wastewater. The Conceptual Design Report only sets out treatment options, it does not recommend a treatment process, this will be contained in the consultant's Feasibility Report, along with costing.

7.2 Wastewater Energy Resource Recovery

The Conceptual Design suggests that the Volatile Solids that are produced as a result of treatment process can be used to generated energy. This can be done through either anaerobic digestion or solid biomass. Tables G and H of the report indicate cost information, see Table 16 for a summary.

Table 16: Renewable energy related costs

Installed Costs for a 20-year Term					
RE	**Installed Cost[1]**		**Net Capacity Factor**	**Annual Degradation**	
Anaerobic Digestion	$8,177		75%	0%	
Solid Biomass	$5,370		91%	0%	
Operating Cost Inputs – Year 1 Expenses (subject to inflation)					
RE	**Fixed O&M** (US$/kW- yr)	**Site Lease** (US$/kW-	**Insurance** (US$/mille)	**Project Mgmt**	**Land Tax[3]**
Anaerobic Digestion	$300	$13	0.4% of	$18	0.95%
Solid Biomass	$238	$13	US$27/kW-	$18	0.95%
RE		Feed-in Tariff (US$/kWh)		Allocation	
Anaerobic Digestion, up to 1 MW		0.2213		2 MW	
Solid Biomass, up to 1 MW		0.2613		2 MW	

With a flow of 5,100 m^3/day it was estimated that with anaerobic digestion 550m^3/day of methane gas could be produced for renewable energy (Integrated Sustainability, 2021 p19). A conventional activated sludge process is expected to produce approximately 0.19 kg of Volatile Solids/m^3 of wastewater treated. The amount of methane that can be produced through anaerobic digestion is about 250 m^3 of methane per tonne of Volatile Solids with a conversion rate of 10 kWh/m^3 of methane.

However the Feasibility Report (2021) on page 23 concludes that the amount of energy that could be recovered is,

> *" too small to justify the capital cost of attempting to anaerobically digest the biosolids at the BSTP. Taking into consideration the operation of anaerobic digesters and the management and energy recovery from biogas requires highly skilled qualified technical staff, anaerobic digestion and bioenergy recovery at the BSTP is not recommended."*

Therefore, this potential benefit is not included in this financial and economic analysis.

7.3 Nutrients

Wastewater contains nutrients; nitrogen and phosphorus which if not removed can have a negative impact on the environment. The nutrients can be removed through biochemical processes to ensure that the treated water conforms to effluent discharge standards. Nutrients can also be recovered through treatment processes and the resulting material used as a fertilizer. Approximately 306 kg/day of nitrogen and 31 kg/day of phosphorus could be recovered from a flow of 5,100 m^3/day (Integrated Sustainability, 2021 p19). Of this it is noted that for the phosphorus, 50% could be removed and sold – 55 tonnes per year at a price of US$1,600/tonne, with the rest in the residual biomass that could be applied to agricultural land.

7.4 Sludge

Only a small percentage of wastewater is not water and the treatment processes very broadly produce a liquid component - water and a solid component - sludge/silage. The solid component contains biomass and nutrients and as long as it does not contain pathogens, heavy metals or other toxic contaminants it can be used in agriculture. The European Union promotes the use of sewage sludge but regulates it use to prevent harmful effects. The Conceptual Design Report indicates that at a flow of 5,100 m^3/day and making assumption regarding the composition of the wastewaters that there would be a loading of 2,000kg/day of volatile suspended solids. This would be reduced through dewatering. Treated sewage sludge can be sold as a fertilizer/soil amelioration product.

7.5 By-product recovery

An option that has been suggested in the Feasibility Report is the setting up of a facility that would take the sewage sludge and process it for energy recovery, the recovery of nutrients and the production of bio-solids which could be sold as a fertilizer or soil conditioner. Such a facility could be financed and operated by the private sector. It is understood that such a facility would also accept other forms of waste from other industries and that this would be needed to be able to achieve input volumes to make such a facility commercially viable. It is also understood that the working hypothesis is that sewerage sludge from the treatment works would be provided at no cost, which is regarded as a questionable assumption.

How such an option might impact on the eventual sewage treatment plant upgrade configuration and whether there would be any capital and operation costs savings is not clear at this time.

8. Financial aspects

8.1 Introduction

In this section the basic financial and economic parameters for inclusion in the model are outlined. These include inflation and discount rates, the capital and operational cost estimates of the various components of the upgrading of the Bridgetown and South Coast wastewater systems and including the infrastructure required for the beneficial use of the treated wastewater. The cost estimates have been taken from existing reports where available. It should be noted that some costs were not available as the reports containing them have not yet been completed. The section also sets out the basis for the calculation of the potential income that might be generated. The basis of the assumptions used for the expenditures and the incomes have been described.

8.2 Financial parameters

8.2.1 Inflation

Barbados' average inflation rate since 2000 is 3.66% - as compared to an average of 3.55 since 1985. The annual Inflation and Consumer Price Indices are shown in Figures 24 and 25. These show the overall impact of changes in prices and are of interest as they would affect the operational costs associated with running the sewerage systems. However, they are not necessarily applicable. It would be preferable to consider the effects of wage inflation, power costs and other goods and services to have a more accurate reflection as to how costs might increase over time. Details of wage inflation are sourced from the Central Bank of Barbados.

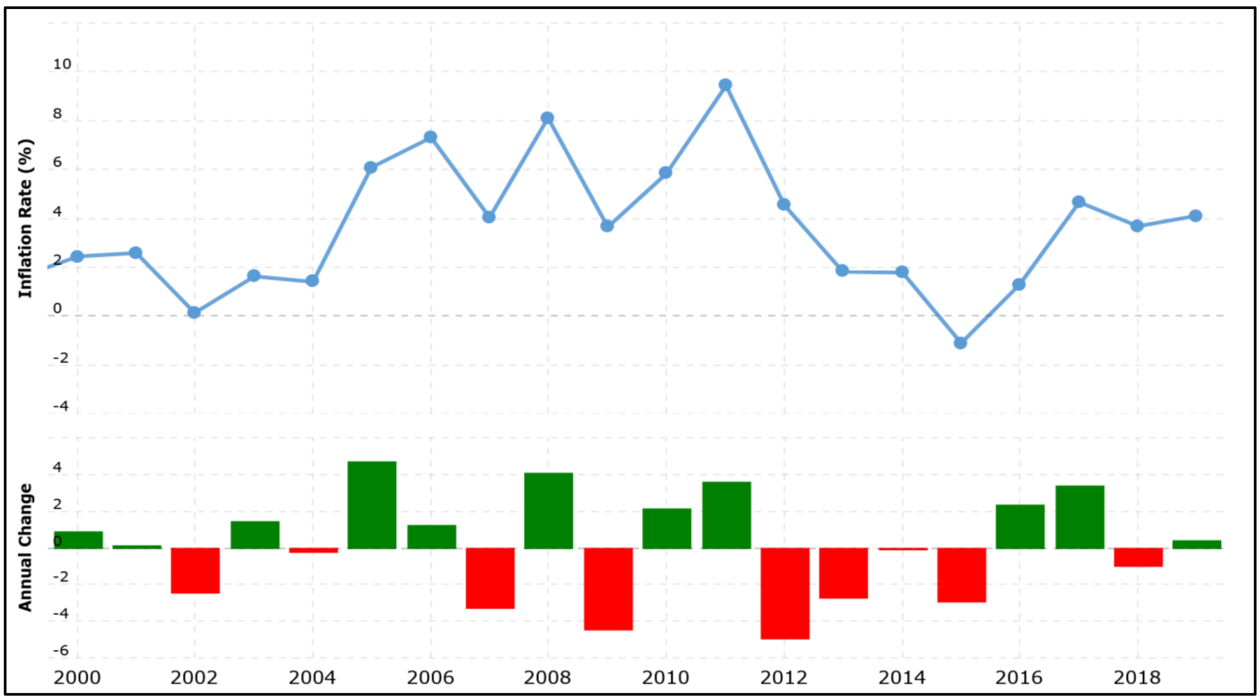


Figure 24: Annual Inflation Rate – Barbados (source: Central Bank of Barbados)

Figure 25: Change in Consumer Price Index - Barbados

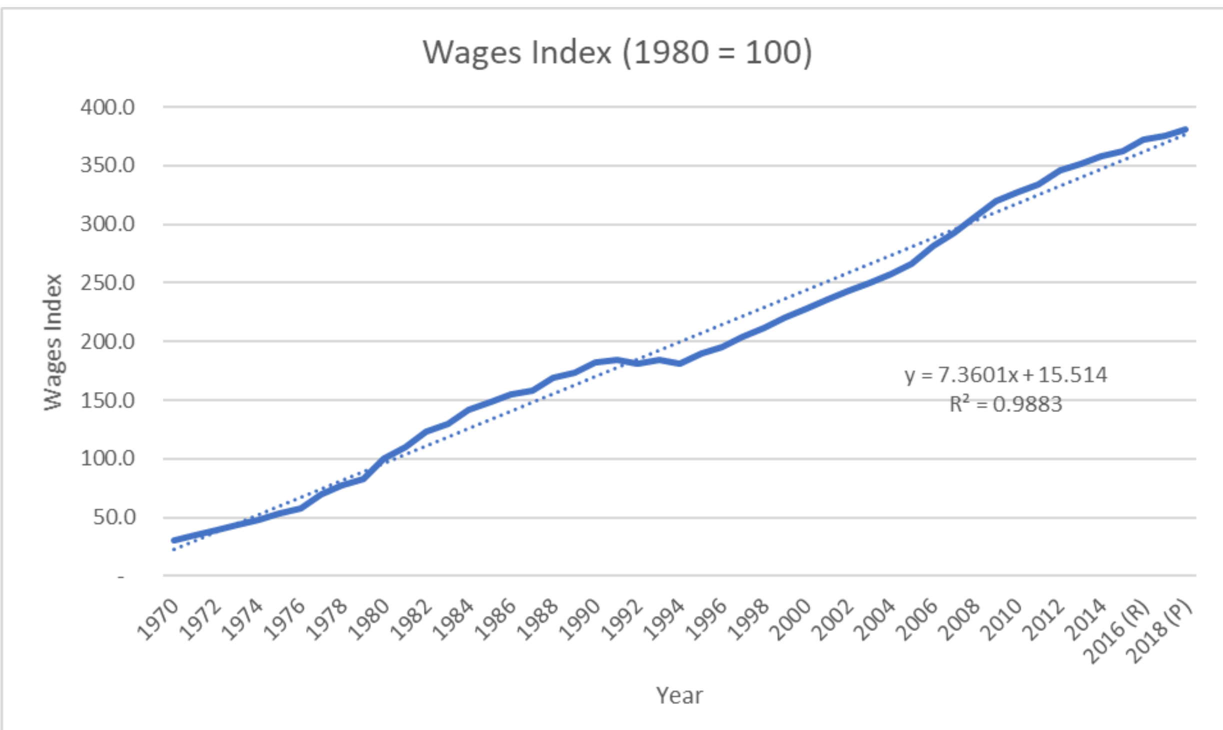


Figure 26: Wages Index

8.2.2 Discount and Interest Rates

The question of what discount rate is to be used for the evaluation of infrastructure projects is a subject that economists are still debating. A recent IDB Technical Note (Campos, et al., 2015) explore various approaches to the use of social discount rates (SDR) for public projects, noting that recent developments have considered constant and declining SDR. Declining SDR are said to be more appropriate for long-term projects particularly those that deal with environment and infrastructure. However, how the declining (hyperbolic) rates are determined is an open question. The point of discounting in this context though is to aid the determination of whether or not a project could go ahead, given that funds are scarce and that there are other opportunities for development which also require funding. The choice of discount rate for evaluation depends on country conditions. Table 17 shows SDR proposed by certain authors.

Table 17: Suggested Social Discount Rates (Campos, et al., 2015, p25)

Immediate Future	Near Future	Medium Future	Distant Future
1 – 5 years	6 – 25 years	26 – 75 years	76 – 300 years
4%	3%	2%	1%

The World Bank and Inter-American Development Bank use a rate of 10% to evaluate projects, Developed Countries tend to use rates between 3% and 8%, whilst Latin American Countries use SDR of between 6% and 12%. A recent paper by Moore, et al., (2020) also looking at Latin America suggested that the rates should be between 2.14% and 5.83% with an average of 3.77%.

The other aspect to consider is the interest rates on capital loans to governments. From a review of Chinese investment loans in the Caribbean it was found that interest rates were between 2% and 3% repaid over 20 years with a five-year moratorium. The Central Bank of Barbados's Bank Rate is set at 2%. The loan conditions of the Green Climate Fund are shown in Table 18.

The figures for interest rates on loans and grace periods are used to determine the financing cost associated with loans.

Table 18: Green Climate Fund Concessional Loans

Table 2: Terms and conditions of outgoing concessional loans to the public sector

	Currency	Maturity (years)	Grace period (years)	Annual principal repayment years 11–20/6–20 (% of initial principal)	Annual principal repayment years 21–40 (% of initial principal)	Interest	Service fee (per annum)	Commitment fee (per annum)
High concessionality	Major convertible currency	40	10	2%	4%	0.00%	0.25%	Up to 0.50%
Low concessionality	Major convertible currency	20	5	6.7%	NA	0.75%	0.50%	Up to 0.75%

8.3 Costings

The costings included are based on the various reports addressing the collection, treatment and use of treated and reclaimed wastewater that have been produced, most recently the Baseline Report (Integrated Sustainability Consultants Ltd, 2021), Conceptual Design Report (Integrated Sustainability Consultants Ltd, 2021), Feasibility Study (Integrated Sustainability Consultants Ltd, 2021), the South Coast Reclamation Pre-feasibility Study (AECOM, 2020) and the Cost Benefit Analysis (Agricultural Planning Unit, 2021) as well as the Belle Feasibility Study (Stantec, 2004), the Report on Effluent Reuse Apes Hill, Royal Westmoreland and Sandy Lane Golf Courses (Stanley International & Klohn-Crippen, 1997) and the Water Augmentation Project (CDM, 2006). At the time of writing the Feasibility Study for the Upgrading of the Bridgetown Sewage Treatment Works was not available. This section sets out a format for the inclusion of costs and includes capital and operational costs to inform the development of the Financial and Economic Model. When fuller cost details are available they will be included in the model.

8.3.1 Bridgetown

The capital costs shown in the table below are subject to updating. The assumptions on which the costs have been arrived at are given in the explanatory notes.

Table 19: Capital Cost Estimates - Bridgetown

Description	Capital Cost (Bds$)	Implementation Years
Upgrading of the Bridgetown Sewage Treatment Plant[1] Conventional Activated Sludge Process Allowance for general refurbishment & site works	57,366,000 6,000,000	2022 – 40% 2023 – 40% 2024 – 20% 2022 – 100%
Miscellaneous Upgrades (see Table 5) [2]	3,540,000	2022 - 2024
Bridgetown Phase 1 - Chapmans Lane - Fontabelle - New Orleans sewering[2]	20,140,000	2022 – 2023
Bridgetown Phase 2 - Licorish/Belle/NW Ivy sewering[3]	8,100,000	2023 -2024
Bridgetown Phase 3 - NE Ivy/Tichbourne/Kingston sewering[3]	5,350,000	2024 – 2025
Bridgetown Phase 4 - Ivy/Welches sewering[3]	8,100,000	2025 - 2026
Hyatt Ziva Hotel and Condominium Complex Bay Street	No capital cost to BWA – connection to existing collection system	2022
Waterfront - Cavans Lane Redevelopment	No capital cost to BWA – connection to existing collection system	2025
Bridge House Redevelopment	No capital cost to BWA – connection to existing collection system	2027
Carlisle House Redevelopment	No capital cost to BWA – connection to existing collection system	2030
Bridgetown CBD Transformation	No capital cost to BWA – connection to existing collection system	2030
Bridgetown Municipal Area Sewering[4]	94,000,000	2030 - 2035
Reuse Options Infrastructure		
Option C Table 15 Reclaimed Water Pipeline and Pumping Installation to Jackson & Neils [4]: 9 km pipeline, 6 injection wells, pump station & Reverse Osmosis Plant	9,000,000 1,200,000 4,400,000	2023–50% & 2024–50% 2023-100% 2023-60% & 2024-40%
Option D Table 15 Reclaimed Water Pipeline to Spring Garden Desalination Plant (3 km pipeline, 3 injection wells, & pump station) [4]	3,000,000 600,000	2023-100%

1. Based on assumed application to Green Climate Fund
2. Based on BWA estimate
3. Based on 2004 Stantec report adjusted for inflation
4. Based on costs provided in Appendix Financial Analysis of the Integrated Sustainability Feasibility Report

The Financial Analysis Report includes capital costs incurred for upgrading and replacement after the first ten years of operation, see Table 20.

Table 20: Capital Expenditures

	Years 1 -10	Years 11-20	Years 21-30
Bridgetown Sewage Treatment Plant	57,366,000	5,800,000	9,800,000
Bridgetown Municipal Area Sewering	94,000,000		9,400,00
Option C			
Pipelines	9,000,000		1,000,000
Reverse Osmosis Plant	4,400,000	1,000,000	1,000,000
Injection Wells	1,200,000		
Option D			
Pipelines	3,000,000		400,000

Operational costs are taken as per Exhibit 4 of the Financial Analysis together with costs calculated from the General Ledger and averaged over time.

Table 21: Operational Cost estimates - Bridgetown

Description	Type	Amount per year
Bridgetown Sewerage System		
Personnel • **Plant & Collection**	Fixed with allowance for grade increase for higher skills	Bds$1,958,850
Power costs	Variable with water treated[3]	Bds$0.26/m^3
Transport	Fixed	Bds$250,000
Miscellaneous costs	Fixed	Bds$300,000
Equipment rental	Fixed	Bds$10,000
Materials and supplies	Fixed	Bds$50,000
Maintenance and repair	Fixed	Bds$400,000
Operational expenses	Fixed	Bds$540,000
Reuse Options Infrastructure		
Option C • **Power**	Variable- includes the power for Reverse Osmosis plant and pumping costs[4].	Bds$20/m^3

[3] The Feasibility Report notes that the average annual electricity cost for the existing plant has been US$470,000. Assuming that the average daily flow calculated in this report is correct (4,500m^3/day), this implies that the electricity cost of water treated is Bds$0.58/m^3. However, the Feasibility Report says that the electrical power consumption for the proposed Conventional Activated Sludge process is US$430,000 per year for 9,000m^3/day (p34), implying that the electricity cost is Bds$0.26/m^3. For this study we accept the figures in the Feasibility Report.

[4] The Feasibility Report does not distinguish between the power consumption for RO and CAS, but the Financial Assessment Appendix does. The variable power cost is based on the difference shown in Exhibit 4.

• **Operation & Maintenance**	Variable for RO plant Fixed for injection wells	Bds$20/m^3 Bds$20,000
Option D • **Power** • **Operation & Maintenance**	Variable Fixed	Bds$0.02/m^3 Bds$20,000

Personnel costs have been increased on the assumption that an upgraded plant will require different and higher-level skills. There is allowance for an increase in personnel handling the collection system when the system is expanded. Other costs are assumed to remain fixed. For the Reuse options it is assumed that no additional personnel will be required but allowance is made for power cost and for routine and preventative maintenance.

8.3.2 South Coast

The capital cost estimates have been taken mainly from AECOM Pre-Feasibility Report and the Cost-Benefit Analysis Report as these contain some estimates.

Table 22: Capital Cost Estimates - South Coast

Description	Capital Cost (Bds$)	Implementation Years
Upgrading of the South Coast Plant	Bds$128,000,000	2022-2023
Option A - As per scenario X1 in Cost-Benefit Analysis to supply River Plantation St Philips area	Bds$82,600,00	2022-2023
Option B – As per the Pre-Feasibility Report's Scenario B to supply Gibbons Bog area	Bds$77,900,000	2022-2023
Carlisle Bay Beach & Needhams Point Precinct Development	No capital cost to BWA – connection to existing collection system	2025-2040
Expansion of collection coverage for the South Coast	Bds$40,000,000	2025-2030

The Benefit Cost Analysis Report notes that implementing either Option A would reduce the need for the proposed desalination plant at River Plantation, which has been costed at Bds$25,250,000 and that this should be set against the increased cost of building the reclaimed water distribution system. This only holds for Option A and adopting Option B would not remove the need for a desalination plant should further development of the River Plantation area go ahead.

In respect of operation and maintenance costs for the South Coast, none of the consultant's reports provide any figures. This is particularly of concern when it comes to power requirements and chemicals. Other costs have been derived through a similar analysis to that of the Bridgetown works, using the booked expenditures and making allowance for expected increases such as would be applicable to staff related costs. The information has been supplemented with similar figures taken from the estimates for the Bridgetown Plant. These are costs for an upgraded plant.

Table 23: Operational Cost Estimates - South Coast

Description	Type	Amount per year
South Coast Sewerage System		
Personnel • **Plant & Collection**	Fixed and allows for grade increase for higher skills	Bds$1,442,050
Power costs	Variable with water treated	Bds$0.54m^3
Transport	Fixed	Bds$190,000
Miscellaneous costs	Fixed	Bds$300,000
Equipment rental	Fixed	Bds$10,000
Materials and supplies	Fixed	Bds$50,000
Maintenance and repair	Fixed	Bds$400,000
Operational expenses	Fixed	Bds$540,000
Reuse Options Infrastructure		
Option A • **Power** • **Maintenance & Operation**	Variable Fixed	Bds$0.10/m^3 Bds$295,000
Option B • **Power** • **Maintenance & Operation**	Variable Fixed	Bds$0.044/m^3 Bds$130,000

Operational costs have been estimated on the same basis as for Bridgetown. The Cost Benefit Analysis report indicates that the annual operation cost of Option A (scenario X1) i.e. supply to River Plantation is Bds$7,800,000 and assumes that 50% of that is attributable to the supply. No further details of the breakdown of operating costs have been provided.

8.3.3 Tanker Service

The purchase cost of water tankers, based on recent tenders are:

18m^3 capacity	Bds$500,000
5m^3 capacity	Bds$250,000

A fleet of say 10 larger tankers would cost Bds$5,000,000 and be capable of delivering approximately 720 m^3 per day with all in service and doing 4 deliveries each per day. Running costs are to be added to this. Assuming that the cost of the tankers would have to be paid back over 5 years then the capital cost component would be Bds$5.25/m^3.

8.3.4 Anaerobic/Biomass Treatment

The Feasibility Report does not propose harnessing the anaerobic process for further energy generation and as a result not additional costs were included.

8.3.5 Photo-Voltaic Solar Panels

The Conceptual Design Report suggests a generation potential of 1.0 kWh/m^2/day. The Bridgetown works already has 975 m^2 of panels installed and roof space for a further 600m^2. There is further space available at the Plant so that overall an area of at least 2,000m^2 could be utilised. In developing the South Coast Works, provision could be made for a similar area for renewable energy generation. This would yield 4,000kWh per day in total at two sites, each with an installed 240kW.

Using figures from the Financial Analysis Appendix the installed capacity at one site is given as 3.91 MW with an installed capital cost of US$1,800/kW giving a capital cost of US$7,038,000 (Bds$14,076,000). Annual running costs can be estimated as a percentage of the capital costs at ~0.1% Bds$7,000 per year for each site. We assume that there is a similar scheme at the South Coast Plant.

8.4 Revenue – willingness to pay, forecasts to be explored

The potential for revenue generation could come from five sources.

1. Income generated from GSC levy,
2. The sale of nutrients/ fertilizer generated from the treatment of the wastewater,
3. From Feed-In Tariff sales of renewable electricity generated from the treatment of volatile solids,
4. From Feed-In Tariffs for renewable energy generated onsite from Photo Voltaic solar panels,
5. Sale of reclaimed treated wastewater.

8.4.1 Garbage and Sewerage Contribution

The income generated from the customers connected to either the Bridgetown or South Coast systems can be calculated directly from the wastewater projections, as these distinguish between residential and non-residential customers. The financial model will do this.

8.4.2 Sale of Nutrients

The calculation of revenue derived from the sale of nutrients depends on the wastewater scenario to determine the volume of solids generated and the potential selling price. Using figures provided in Section 7.3, approximately 0.03kg/m^3 of phosphorus from wastewater could be generated for sale. The Feasibility Report – Financial Analysis suggests the amount of phosphorous generated would be 55 tonnes per year. An indicative price of phosphorus was given as US$ 1,600/tonne (Bds$3,200/tonne).

The remaining stabilized waste activated sludge could generate additional sales as a soil conditioner/fertilizer, but at a lower cost. For calculation purposes a price of Bds$100/tonne is proposed. This equates to the selling price of topsoil from Sustainable Barbados Recycling Centre (SBRC).

For indicative purposes a figure of 0.4kg/m^3 of sludge from wastewater could be used. However, the Feasibility Report does not include the sale of sludge as an additional source of revenue.

8.4.3 Energy from sludge

From the information provided in Section 7.2, it had been estimated that 1 kWh of energy could be produced per cubic metre of wastewater. The applicable tariffs are shown in **Table *16*: Renewable energy related costs**Table 16.

However, the Feasibility Report did not propose using and adding to the anaerobic digestion process the facility to utilise the gasses produced to generate energy. It was suggested that the operation of such a energy generation system was technically complex and that therefore it not be considered at this point in time. Hence, there is no inclusion of income generated from energy from sludge.

8.4.4 Energy from On-site Solar Panels

The Integrated Sustainability Feasibility Report estimated that PV modules would be installed on building rooftops, as well as open spaces within the property, to the extent of approximately 3.91 MW of PV to supplement the existing power provided to the Plant, as well as the power requirement for the proposed Reverse Osmosis Plant identified for Option C. The estimate for the size of the PV system is to make the Bridgetown Plant electricity neutral, as the proposed new PV system, along with existing PV systems at the Bridgetown Plant are used to off-set plant electrical power costs used. It is assumed that the South Coast Plant would have the same.

The 3.91MW installation was calculated to yield 5,278,000kWh of power per year. The applicable Feed-in Tariff for a PV system of between 1 MW and 5 MW is 23.25 Bds cents/kWh. The income generated could be credited to BWA's Renewable Energy Fund.

8.4.5 Sale of Reclaimed Treated Wastewater

At present the BADMC sells water to farmers at Bds\$0.60/m^3. This supplements rain fed agriculture and at that price, water constitutes between 6% and 16% of production costs. For private farmers with their own wells, water constitutes less than 10% of their production costs. For farmers that use water from BWA at the commercial rates, water constitutes at least 50% of their production costs. At the basic commercial rate water is charged at Bds\$4.66/m^3 but for a farmer with say a 1 hectare plot the effective rate would be Bds\$7.40/m^3. BADMC have indicated that their breakeven costs for water supply is approximately BDS\$1.20.

As noted above, discussions with various farmers indicates that they are willing to purchase water and some have indicated that they would pay a slight premium for water with additional nutrients in it. No farmer would go on record to say what they would be willing to pay. Figures of what proportion of production cost water might constitute could not be determined, and anyway this would vary by crop and other factors. Without any willingness to pay survey determining an appropriate unit cost for irrigation water. For calculation purposes revenue generation at Bds\$2.00/m^3 and Bds\$4.66/m^3 can be used.

It can also be noted that Barbadian farmers have been agitating for relief from the GSC levy. They are arguing that this is compromising their profitability. This applies to those who get their water from the BWA and probably affects non-field crop farmers such as those in the dairy, cattle, poultry, pig farming and small ruminant sectors. For these the value of water is probably higher than it is for crop farmers.

8.4.6 Willingness to Pay

The consultants undertaking the conceptual design and feasibility study for the upgrading of the Bridgetown Sewage Treatment Works had been planned to carry out a willingness to pay survey among the Barbadian public. The survey was started but was halted. A limited number of responses were received, 75 in total. This is a very small sample and cannot be a representative sample, the few results that were submitted were analysed. However, the results have not been included here as they are not considered to be a reliable basis on which to make decisions. It can be noted that the 60% tariff increase of 1st August 2018 and the more recent introduction of the Garbage and Sewerage Contribution, although they met with some adverse comments were generally accepted by the public.

9. Economic Aspects

9.1 GHG Emissions

The upgrading of the two wastewater treatment works, the pumping of reclaimed water either for agriculture or MA, and the expansion of sewage collection systems will inevitable increase power consumption. If the additional power were to come from the use of fossil fuels, then there would be an increase in GHG emissions. Some of this could be offset by the use of biogas to generate power by burning the methane produced. However, using methane as a fuel also produces CO_2 and so whilst the emissions may be less than from other sources it is still contributing to emissions. In contract, power generated on site from PV solar panels would not contribute to emissions.

Barbados has set itself a target of becoming a 100% renewable energy and carbon-neutral island state by 2030. To achieve this the Barbados Government together with the IDB has set up the SMART II fund to assist with that transition. At the same time the BWA is exploring the opportunities to become energy neutral (i.e. generate its energy needs from solar and wind power sources).

For the purposes of this report, it is presumed that by 2030 all the power requirements associated with the two sewerage schemes will be met from renewable energy sources. This will therefore avoid GHG emissions that would otherwise have resulted from the increased power demand, noting that power demand will vary across the four economic scenarios outlined in Section 5.4.

The calculation of GHG emissions per unit of power produced depends on the fuel source and mix of sources in a country. These range from 710 $kgCO_{2eq}$/kWh for Hong Kong to 130 $kgCO_{2eq}$/kWh for New Zealand. Barbados has 73MW of installed capacity using natural gas and 166MW of installed capacity using oil. Based on this mix and using 777 $kgCO_{2eq}$/kWh for oil and 429 $kgCO_{2eq}$/kWh for natural gas a figure of 672 $kgCO_{2eq}$/kWh is used to calculate the avoided emissions. The power consumption of the Bridgetown and South Coast systems – the sewage treatment works and the pumping of water for either irrigation, indirect and/or direct potable water recharge, can be calculated based on the volumes treated and transferred.

The energy usage, derived from the Feasibility Report for the upgraded Bridgetown Plant. There are no similar figures available for the upgraded South Coast Plant, however, both plants are of the same capacity and therefore it is suggested that it is reasonable to assume that the figures from the Bridgetown Plant can be used in the absence of better information. The conversion factor as per above is taken as 0.672 tCO_{2eq}/kWh.

Table 24:GHG Emissions by upgrade options

	Bridgetown Plant	South Coast Plant
Upgrade to include CAS	0.45 kWh/m^3 (0.302 tCO_{2eq}/m^3)	
Option C: RO	0.48 kWh/m^3 (0.322 tCO_{2eq}/m^3)	
Option D: Pumping	0.03 kWh/m^3 (0.020 tCO_{2eq}/m^3)	
Upgrade		0.93 kWh/m^3 (0.625 tCO_{2eq}/m^3)
Option A		0.17 kWh/m^3 (0.114 tCO_{2eq}/m^3)

Option B		0.08 kWh/m^3 (0.054 tCO_{2eq} /m^3)

The economic value of the avoided emissions can be calculated using the price of Carbon or Social Cost of Carbon (SCC). The following is an extract from the Executive Summary of an OECD Report *Effective Carbon Rates 2021: Pricing Carbon Emissions through Taxes and Emissions Trading:*

> "The first benchmark, EUR 30 per tonne of CO_2, is an historic low-end price benchmark of carbon costs and a minimum price level to start triggering meaningful abatement efforts. The second benchmark, EUR 60 per tonne of CO_2, is a forward looking 2030 low-end and mid-range 2020 benchmark. The third benchmark, EUR 120 per tonne of CO_2, is a central estimate of the carbon costs in 2030. For the presentation of key results, the report focuses on the EUR 60 per tonne CO_2 benchmark."

Chapter 14 of the OECD Report on Cost Benefit Analysis and the Environment (Atkinson, et al., 2018) discusses the Social Cost of Carbon in detail. As it is concerned with methodological issues it does not make recommendations regarding what the SCC should be but rather discusses reported values. The Report notes that from a survey of over a 1000 experts, the average value was US\$ 54.6/tCO_{2eq}, higher than the value of US\$42 that has been widely cited and used. In France a figure of US\$27/tCO_{2eq} was taken as the starting point escalating at 5.8%/year up to 2030 and then at 4.5%/year thereafter. In Table 14.4 for a 'mid-range' scenario the following rates were given:

Table 25: Social Cost of Carbon Estimates (US\$/tCO_{2eq})

2020	2025	2030	2035	2040	2045	2050
\$42	\$46	\$50	\$55	\$60	\$64	\$69

For calculation purposes it is proposed that the figures in the above table be used. The social cost of carbon per tonne of CO_2 equivalent together with the annual energy consumption in kWh allows the annual avoided costs of GHG emissions to be calculated.

9.2 Health Improvements

In contrast to water supply and sanitation services, the benefits of waste-water treatment are less obvious to individuals and more difficult to assess in monetary terms. The consensus on the need for increased urban wastewater treatment as well as safe disposal of its residues has therefore developed more slowly, probably also due to the relatively high costs of such interventions. There is a large body of literature on the benefits of improved sanitation from across the globe though the focus tends to be on developing countries. A widely cited figure is that for every US\$1 invested in sanitation there are US\$8 in benefits, both direct and indirect. The benefits derive from lower health costs, more productivity and fewer premature deaths, as well as other social and environmental gains. How this can be broken down and applied to Barbados has not been done and give that most of the population already have access to improved sanitation, moving from septic tanks to a centralised sewerage system is unlikely to produce benefits of the scale noted in the literature.

The reduction in the burden of diseases attributable to improved sanitation can be measured in Disability Adjusted Life Years (DALYs) where one DALY represents one year of healthy life lost. An approach that might be adopted is through Benefits Transfer whereby the results for similar studies are adjusted and used to estimate the potential benefits. However, a scan of the literature did not provide any suitable examples or studies that can be used. The Cost-Benefit Analysis for Implementing the West Coast Sewerage Project (CDM, 2008) adopted an approach based on the avoidance of loss of productivity attributable to the contraction of health problems associated with bathing.

Assuming that those who are currently connected to the sewerage systems already benefit, the additional health benefits only accrue to those who would be connected in the future. Following the method used in the West Coast Sewerage Project report, the potential benefits are calculated as follows:

- Average income Bds$34,300 per year and this reflects the value of productivity,
- Average work year 250 days,
- Assume households in the to be sewered areas lose one day per year through sanitation related issues,
- Value of the avoided costs is the number of households multiplied by 1 day multiplied by the value of daily productivity.

9.3 Improved Marine Environment

The West Coast Sewerage Project Report (CDM, 2008) identified the following benefits from the sewering of the West Coast;

- Reduced beach erosion
- Avoidance of beach closures
- Enhanced sport diving, and
- Enhanced submarine tours

It did not place a value on the improvements in the quality of the marine environment but it is assumed that it used the sports diving and submarine tours as proxies for improved quality of the marine environment.

An alternative method of valuing improvements to the marine environment would be to draw on the Willingness to Pay studies undertaken by Schuhmann, et al. (2017). From their study they noted:

> “Considering the prices that respondents reported paying for airfare and lodging for a one-week stay in Barbados (US$1,669), the WTP values suggest that the average visitor would be unlikely to visit if sea-water quality were to reach the condition of “poor,” where the probability of an infection were greater than 10 percent, or if storm risk were “high” (10 days out of 100 interrupted by storms).”

On the other hand if there were moderate improvements visitors would be willing to pay at least US$2,000. Further work by Schuhmann, et al (2019) demonstratd that percetions of deterioration of the quality of the coastal and marine environment had a negative impact on visitors intention to return, whilst maintenance or improvement had little impact.

Whilst the results of the studies are considered to be reasonable there are difficulties in applying them. First of all to what number of tourists should the values be applied, second, over what area should the improvements or avoided degradation of conditions apply, and could all the avoided degradation be attributable to improved wastewater treatment.

The South Coast area is already serviced by a sewerage system and so it could be argued that only under a condition where coverage was extended would there be some further improvement. This means that the main area of benefit would be associated with Bridgetown and the marine environment from Batts Rock in the north to Bridgetown Port in the south.

For the purposes of calculation of potential benefits – avoided losses – the value of improvements will not be used; US$1,600. The numbers of persons willing to pay to avoid degradation is taken as the number of tourist staying on the South Coast, the main tourist area, with 10% visiting the area in question. Tourist numbers for the South Coast are to be calculated from the figures of hotel water consumption divided by the average consumption taken from the literature as 840 litres per guest night (Charara, et al., 2011). Alternatively, they could be derived independently making varying tourism growth assumptions.

9.4 Reduced Run-off

The expansion of sewerage coverage should not have any effect on reducing run-off from storm and heavy rainfall events as these are designed to operate as sanitary sewers. In fact, the BWA are making efforts to eliminate the introduction of stormwater into their sewers by engaging with households and property owners. Hence no potential benefits are included.

9.5 Water Availability

9.5.1 Impact of Climate Change

As discussed in Section 3, climate change is expected to have an adverse impact on water availability. If the amount of water that can be abstracted from the groundwater aquifers decreases, all other sources of supply being held unchanged (for example no increase in existing desalination capacity), then the level of demand would have to be constrained to what was available. The difference between the existing situation, with no climate change and a future situation with climate change but no adaptive and mitigatory interventions would indicate the extent of the impact of climate change on water supplied.

The future level of water consumption would be made up of the projections made in Section 5.4: Projections and the projected increase for the rest of Barbados. The existing water demand can be derived from figures provided by the BWA and hence the relative contribution to total water demand of the Bridgetown and South Coast systems and the Rest of Barbados can be calculated. For future projections of the water demand of the Rest of Barbados assumptions can be made; under the No Growth, Business as Usual scenarios there is a 0.1% per year growth, for the other scenarios a growth of 0.5% is assumed – column D. For calculation purposes it is assumed that the available water supply will be allocated in the same proportions as the contribution to water demand, irrespective of scenario.

With this approach the level of constrained demand for each water demand scenario of and climate change scenario can be calculated, see Table 26. In Table 26 it is assumed that private abstraction for non-potable water uses will continue at the same level, irrespective of climate change. The difference between column K – the required groundwater abstraction to meet the total demand and column L the groundwater safe yield represents the constraint on demand brought about by climate change. As indicated, this can be distributed between Bridgetown and the South Coast and the Rest of Barbados.

Table 26: Impact of Climate Change on Water Supply

A	B	C	D	E	F	G	H	J	K	L		
Scenario	Total Water Demand (Mm^3)	Bridgetown & South Coast Water Demand (Mm^3)	Rest of Barbados Water Demand (Mm^3)	Losses[1] (Mm^3)	Total Potable Production (Mm^3)	Non-potable Production[2] (Mm^3)	Total Demand (Mm^3)	Desalination[3] (Mm^3)	Required Groundwater Abstraction (Mm^3)	Safe Yield (Mm^3)		
										No climate change	RCP4.5	RCP 8.5
Current situation	31.957	3.555	28.402	19.981	51.938	10.590	62.528	10.000	52.528	65.700	-	-
No growth (2050)	33.296	4.030	29.266	14.270	47.566	10.590	58.156	15.000	43.156		31.000	29.000
Business as usual (2050)	34.185	4.919	29.266	14.651	48.836	10.590	59.426	15.000	44.426		31.000	29.000
Development & Growth (2050)	40.222	7.236	32.986	17.238	57.460	10.590	68.050	15.000	53.050		31.000	29.000

1 Future losses are calculated at 30% of total potable water production which considers current planned mains replacement.
2 Non-potable water production is the assumed private groundwater abstraction mostly for agricultural purposes.
3 Desalination capacity is for the upgraded Spring Garden Plant only

Table 27: Impact of Climate Change on Water Supply Surplus/Deficit

Scenario	Bridgetown & South Coast Water Demand as % of Demand	Rest of Barbados Water Demand as % of Demand	Headroom (Mm^3/a)		
			No Climate Change 65.700 Mm^3/a	RCP 4.5 31.000 Mm^3/a	RCP 8.5 29.000 Mm^3/a
Current situation	10%	90%	13.172	-	-
No growth	12%	88%	22.544	-12.156	-14.156
Business as usual	14%	86%	21.274	-13.426	-15.426
Development & Growth	18%	82%	12.650	-22.050	-24.050

Table 27 is indicative of the potential impact Climate Change could have on Barbados' water supply and the level of constrained demand in the absence of any other actions to address the deficit. It is assumed that the non-potable production, column G in Table 26, would continue to be met from groundwater sources. It is also assumed that the level of constrained demand would be in the same ratio of demand as shown under the Bridgetown and South Coast Water Demand column.

The economic value of the constrained water demand can be calculated using a shadow price for the demand for water.

This analysis does not consider the possible impact on the constrained water demand of the various proposed project intervention options. The project interventions are expected to augment water supply and hence reduce the constrained water demand. The extent to which the proposed adaptation measures would reduce the constrained water demand represents the economic benefits to society.

9.5.2 Adaptations to Climate Change

There are two broad options for the use of treated reclaimed water. The first as proposed is that it could be used to support the expansion of irrigated agriculture. The second is that it could be used to supplement the potable water supply either through indirect reuse via Managed Aquifer Recharge (MAR) i.e. injection into the aquifer or direct potable water reuse by supply via the Spring Garden Brackish Water Reverse Osmosis Works.

There have been different assumptions regarding the amount of water that could be used for irrigation. The AECOM Feasibility Report and the Cost-Benefit Report by the Agricultural Planning Unit both assumed that all treated water from the South Coast Plant would be supplied for irrigation use. However, the AECOM Report included injection wells for groundwater recharge, implying that not all the water would be used for irrigation, some would be used for MAR. The Integrated Sustainability Feasibility Report for the Bridgetown Plant makes assumptions regarding the amount of treated water that would go towards supporting irrigation and how much would go to MAR. That Report suggests that 40% of treated water would go for irrigation with the rest for MAR. However, consideration of the when supplemental irrigation would be required in the face of climate change suggests that it would be for at least nine months of the year and possibly 11 months under RCP8.5 by 2050, see Figure 27. If this is the case then only a small amount would be available for MAR, in other words between 75% and 90% would be required to support irrigation. However, the Report also suggests that 30% of the volume applied would act as recharge. How much of the 30% would then be available as indirect potable water reuse is unclear, given that it would not all be intercepted by abstraction/production wells. This depends on the distance between the point of recharge and abstraction; the greater the distance the less that would be intercepted. For calculation purposes for the potential amount intercepted for the South Coast system is assumed to be 20%. For the Bridgetown system, as per the Integrated Sustainability Feasibility Report, a figure of 70% is used. However, we differ from that Report in assuming that more than the suggested 40% of treated reclaimed water from the Bridgetown Plant would go for irrigation. In line with the argument that due to climate change, supplementary irrigation would be required for at least 75% of the time, and probably for longer. The proposed contribution is set out in the two figures below.

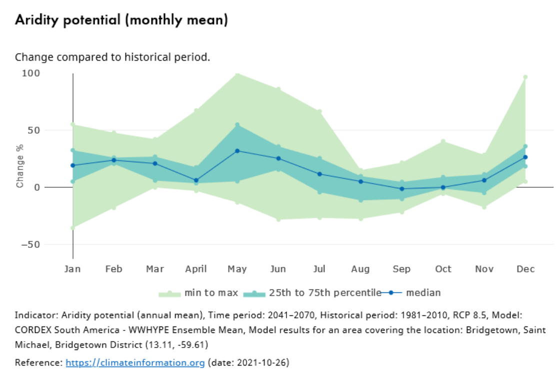


Figure 27: Monthly aridity index under RCP 8.5

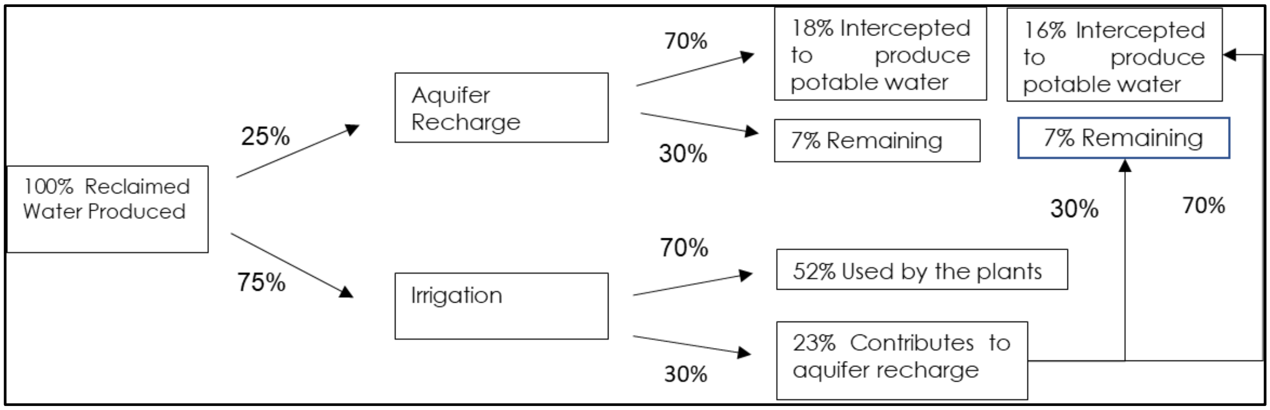


Figure 28: Distribution of Treated Reclaimed Water – Bridgetown System

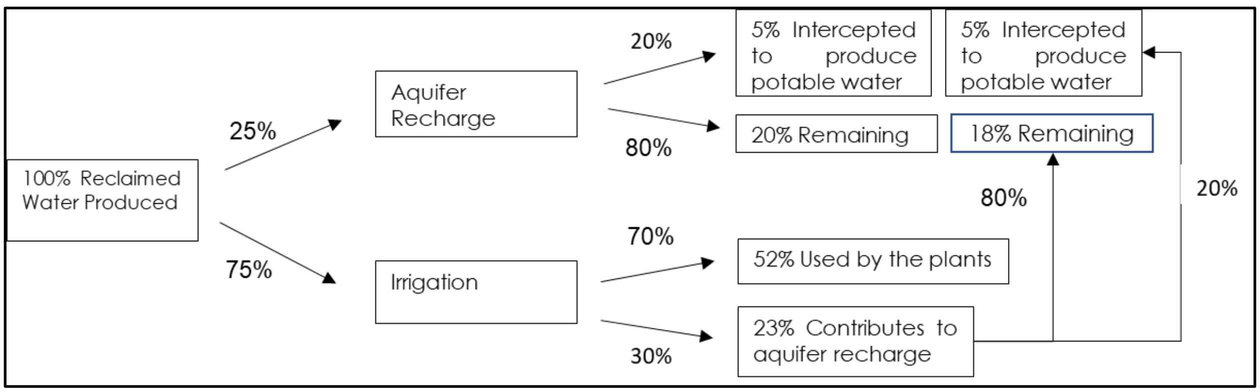


Figure 29: Distribution of Treated Reclaimed Water – South Coast System

Hence from the Bridgetown system of the volume of treated reclaimed water supplied, 34% could augment potable water supplies indirectly and 14% would not be intercepted. Concomitantly, for the South Coast system, 10% could augment potable water supplies indirectly with 38% not being intercepted and diffusing into the marine environment.

The alternative to the above would be to direct all treated reclaimed water to augment the existing feed into the Spring Garden Desalination plant, from both the Bridgetown and South Coast Sewage Treatment Plants. This would be Direct Potable Reuse and the full volumes produced would be used.

9.5.3 Irrigated Agriculture

Much of the focus so far has been on the use of reclaimed treated wastewater to support and even grow the irrigated agricultural sector of the economy. The Cost-Benefit Analysis (Agricultural Planning Unit, 2021) provides indications of the potential benefits that could arise from the support and transformation of agriculture in increasing food production and by extension employment and income opportunities.

It is estimated that some 374 additional jobs could be created which would equate to that number of families being supported by regular waged income. Using the average income given above of Bds$34,300 this could generate an addition BDS$2,400,000 per year in revenue for the

Government based on income tax and VAT on household expenditures. By creating more secure waged employment this could potentially lessen the burden on welfare services.

The increased profitability of farming would have a multiplier effect on the local economy (the increase in farm profitability was not calculated, only the profitability per acre) increasing farm level expenditures. At the same time, increased local food production would substitute the importation of fresh vegetable. In 2019 imports of fresh vegetable amounted to Bds$67 million according to the MAFS. How much could be substituted has not been calculated by the Ministry but assuming a 20% substitution it could be a savings of Bds$13 million per annum in foreign currency requirements.

The above is based on the figures for the development of the River Plantation area. An equivalent analysis for the development of the Gibbons Bog and associated areas was not undertaken. The area is approximately half of that of River Plantation but given the reduced water requirements the potential benefits could be equivalent to those considered under scenario X3 by MAFS. The number of jobs created would be lower, 238 and hence the tax take would be less, being Bds$1,500,000. It is assumed that the import substitution remains unchanged.

To this should be added the impact of water from the Bridgetown Works. The potential volumes should sewerage coverage be extended would be much greater. For the purposes of calculation, the potential impact is taken as being similar to the full development of the River Plantation area.

Irrigation Area	Tax & VAT	Import Substitution
River Plantation	US$1.2 million per year	US$6.5 million per year
Gibbons Bog	US$0.75 million per year	
Neils, Salters	US$1.2 million per year	

In addition to the above economic contributions from the provision of treated reclaimed water for irrigation there is the economic value of the water itself. This is sometimes referred to as the shadow price and is the marginal value produced by the use of a unit of water and relates to the efficiency gain from reallocation of a resource. It is not the price that the water is sold at. The shadow price of irrigation water would only apply to the water that could be made available. In both the Bridgetown and South Coast systems it would apply to the 75% of the volume that could be made available for irrigation.

9.5.4 Managed Aquifer Recharge

As indicated above, an alternative use would be for either indirect or direct potable water recharge. Using the reclaimed water in this manner would serve to offset the decline in aquifer yields. Utilising treated wastewater for either direct or indirect potable water reuse would imply that any agricultural development for the increased use of irrigation water would have to be either put on hold or considered separately utilising alternative sources.

The potential impact on potable water supply depends on several factors. If direct potable supply is used then it can be assumed that all the treated water goes back into supply – via the Spring Garden desalination plant.

If there was indirect recharge then only a proportion of the treated reclaimed water would be available, as discussed in Section 9.5.2 and set out in Figures 28 and 29. An alternative, which is not considered in the modelling, would be to use all the treated reclaimed water for MAR either upstream of The Belle pumping station or upstream of the Spring Garden Desalination Plant.

Other factors include the climate change scenario as this would determine the level of constrained demand. It also depends on assumptions regarding losses from the water distribution system. There are investments being made into water mains replacement which should reduce physical/real losses; an assumption is made that levels would drop from the current 38% to 30%. Reducing real losses to below 30% would require significant investment in an aggressive Non-Revenue Water Loss Reduction programme. The principal factor though is how much water would actually be available for recycling and this depends on what future developments are implemented. The projection scenarios outlined in Section 5.4 are used to set the level of future development.

Recycling whether through Direct or Indirect Potable Reuse will improve the ability of the supply system to meet the expected water demand. The extent to which will be investigated through the modelling. The degree to which the constrained water demand is reduced represents the economic benefit to society, determined by the volume multiplied by the shadow price of water.

10 Summary

This Baseline Study Report sets out the basis and assumptions on which the Financial and Economic Model is built. It sets out Barbados' current economic situation and notes that the Terms of Reference require a 20 to 30-year wastewater projection. For the purposes of this report a planning horizon of 2050 was adopted. This raises questions around how future economic development over a 30-year period might impact the demand for wastewater services as projections based on past trends would not be a sound basis for analysis. To accommodate this the use of scenarios is proposed ranging from pessimistic to optimistic assumptions of future economic development; four scenarios with different growth assumptions have been set out. Work by Drakes, et al. (2020) indicated that assumptions of socio-econoic development had a greated impact on water demand than climate change assumptions.

The review of the impact of climate change on Barbados and its water resources focused on two aspects. The first aspect was the potential impact on future available safe aquifer yields, given that Barbados presently relies on groundwater for a large part of its water supply. The review of available literature indicates that safe yields could decrease by around 50% from current levels. The second aspect was the potential impact on water consumption and hence wastewater generation. Here there is less literature to act as guide. There is some suggestion that water consumption would increase with temperature, once average temperature reach a tipping point of between 28ºC and 30ºC, however this may be regarded as uncertain.

The current state of wastewater services and management in Barbados has been reviewed. There is a clear need, irrespective of whether or not this project goes ahead for the management of wastewater service to be improved. Similarly, the day to day operation of wastewater services needs to be improved, which has been commented on by other consultant's reports. Without attention to these two aspects, the upgrading of the two wastewater collection and treatment systems; Bridgetown and the South Coast, are more than likely to show some initial improvement but would be followed by deterioration of plant and service. The general state of the Barbados Water Authority's record keeping and Management Information Systems leaves much to be desired if it is judged by the quality and timeliness of information provided to this study. The cost information provided by the BWA is to be used as basic information for the model to inform calculations. However, discussions with BWA personnel point to questions over the accuracy of the information provided with respect to operational expenditures. Furthermore, detailed information on capital expenditures is considered incomplete.

In order to estimate the volumes of wastewater flows, in the absence of measured inflows to the two treatment works, water consumption records of customers connected to the two systems were analysed. First, there are many anomalies and variations in the data which it is clear have not been investigated. It is to be hoped that once the automatic meter reading is implemented that the anomalies can be removed. The analysis demonstrates the impact that Covid-19 has had on consumer behaviour; increasing residential demand and decreasing commercial activity, with the hotel sector being the most heavily impacted. What emerges from the analysis is that in general wastewater flows have been over-estimated, even before the impact of Covid-19 is taken into consideration, and that the two Sewage Treatment Plants are operating well below capacity. The results were discussed with BWA personnel who have indicated that the analysis is a fair reflection of their understanding of the performance of the systems.

In making future estimation of wastewater generation, the known developments have been included, where appropriate, using information from applications to the Town and Country Development Planning Office. The suggestion of extending the Bridgetown sewer collection system has been re-evaluated and it is our conclusion that the previous work has over-estimated the potential wastewater generation. The scenarios approach has been built into the Financial and economic Model, enabling the impact of different scenarios to be evaluated. The implication of the analyses is that for the foreseeable future there is little need to expand the Bridgetown treatment works.

The potential uses of treated wastewater and by-products have been considered and based on information contained in other reports estimations have been made with respect to volumes. In some cases, there is not enough available information to complete the calculations; for example, there are questions how biogas from sewage sludge might be generated and how much. With respect to the use of reclaimed treated wastewater, interviews and discussions with the agricultural community suggest broad support and a willingness to use the product. This does not seem to be an issue, more of an issue – raised by farmers – was the attitude of the public and the need for assurances around food safety.

The financial aspects considered the capital and operational costs that would be associated with different solutions to the use of reclaimed treated wastewater. The main focus has been on its reuse for agricultural purposes, noting that the MAFS is seeking to expand agricultural production, particularly in the lands in and around River Plantation in St Philip. An alternative to the River Plantation focused scheme would be to provide water to the Gibbon Bog and associated areas, given that the available volumes of water are less than those projected in the AECOM Prefeasibility Report and the MAFS Cost Benefit Analysis Report. The limiting factor is the available volume of reclaimed treated wastewater, there is more than sufficient land suitable for irrigation and based on discussions with the farming community, demand will outweigh supply.

The final section considers the economic impacts associated with the upgrading to the two sewage systems. The potential benefits considered have included, avoided GHG emissions, the social cost of carbon, health benefits, the marine environment, and increased food security. The section also considers what might be called the social cost of water – the estimated economic impact of climate change on water availability and the resulting constrained demand. This could be mitigated through either the direct potable reuse of treated wastewater in place of its use for supporting agriculture or indirect potable water reuse through Managed Aquifer Recharge associated with providing water for irrigation. The basic analysis suggests that both could counter the decrease in sustainable groundwater yields due to climate change, given certain assumptions.

This content of this report is intended to inform the Financial and Economic Cost Model. As such it is important for there to be consensus and agreement regarding what should and can be included and for the gaps in information to be filled.

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