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COST BENEFIT ANALYSIS

Provision of Reclaimed Water from the Bridgetown Sewage Treatment Plant

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Cost Benefit Analysis for the Provision of Reclaimed Water from the Proposed Upgrade of the Bridgetown Sewage Treatment Plant for Irrigation Purposes

1. Introduction

The Government of Barbados, Barbados Water Authority (BWA) and the Caribbean Community Climate Change Centre (CCCCC) are developing a Green Climate Fund (GCF) project aimed to build climate resilient into the wastewater systems of Barbados. The project addresses challenges facing the wastewater systems particularly those caused and exacerbated by climate change. The project is titled, "The R's (Reduce, Reuse and Recycle) for Climate Resilience Wastewater Systems in Barbados (3R-CREWS)" and broadly addresses the need to upgrade and improve the two existing centralised wastewater systems in Barbados. The two wastewater systems are the Bridgetown Sewage System and the South Coast Sewage Treatment. At present both Sewage Treatment Plants discharge treated water into the marine environment. This practice is increasingly seen as a waste of a valuable resource – water; particularly given the expected negative impacts of climate change on water availability.

In putting forward proposals for the upgrading of the two Sewage Treatment Plants consideration is being given to the uses to which the treated water could be put as this influences the design of the upgrades. In the case of the South Coast Sewage Treatment Plant a decision has been made that treated reclaimed water would be used to support irrigated agriculture in the southern part of Barbados. This was the subject of the Study by the Agricultural Planning Unit of the Ministry of Agriculture and Food Security and published in March 2021. Several options as to where treated reclaimed water could be used to support irrigated agriculture and how much water could be utilised. The Study provided the rationale and recommendation in respect of where the treated reclaimed water was to be used, the basic outlines of the options considered and their associated costs and benefits. The Study built on initial work carried out by AECOM Consultants entitled the South Coast Pre-feasibility Study.

In respect of the upgrading of the Bridgetown Sewage Treatment Plant, the consultants Integrated Sustainability Ltd. in their Conceptual Design and Feasibility Reports, drawing on inputs from the Government Technical Working Group put forward several suggestions for the use of the treated reclaimed water. However, in the absence of a Cost-Benefit Analysis (CBA) the choice of preferred option could not be made on an informed basis. As a result the Technical Working Group requested the Caribbean Community Climate Change Centre (CCCCC) to have a Cost Benefit Analysis produced to guide their decision-making.

This document sets out the work undertaken to develop the CBA and its inclusion in the Triple Bottom Line Analysis. The Triple Bottom Line Analysis takes into consideration not just the financial factors associated with each of the options considered but also the macro Social, Environmental and Economic factors. It therefore provides a balanced and objective approach to inform decision-making. All the work and outputs described were presented to and accepted by the Technical Working Group.

2. Options for Reclaimed Water Reuse

2.1 Options

As indicated above, the Barbados Water Authority is examining the feasibility of upgrading the Bridgetown Sewage Treatment Plant (BSTP) to a modern resource recovery facility. The upgraded facility would provide more advanced secondary treatment and remove the necessity of a sea outfall for disposal of the treated wastewater. The upgraded facility would allow for the treatment of wastewater to a standard that is suitable for groundwater recharge of the aquifer, as well as for edible food crop irrigation. These standards will be in keeping with those recommended by the Environmental Protection Department (EPD).

Using information provided by the Technical Working Group and based on their own assessment of options, the Consultants put forward options for the treated water from the Bridgetown Plant. These are set out in Table 1.

Table 1: Reuse Options (Table P of the Feasibility Report)

Option	Irrigation Route	Aquifer Recharge	Pipeline Length	Irrigible Area[1]
1	BSTP to Waterford (Botanical Gardens) then northwards to recharge point at Trents (Greenwich) (find points or take-offs along the way). Assume 6 injection wells will be included in this option.	Trents and Waterford (to be modelled for impact on nitrates and where the water goes). Treatment using RO is also required to meet irrigation TDS requirements)	13 kms	71 Hectares
2	Extend option 1 all the way to Spring Hall Land Lease, St. Lucy – all other points remain the same. Assume 9 injection wells will be included in this option	Trents and Waterford (to be modelled for impact on nitrates and where the water goes). Treatment using RO is also required to meet irrigation TDS requirements)	27 kms	235 Hectares
3	BSTP to Waterford (Botanical Gardens) with take-off at Hothersal roundabout to Friendship plantation the turn south along ABC H'way and then Turn North along Belle Road up to Lears (Roberts Manufacturing) – irrigation can be done for lands on east and west of that road. Also take in Neil's Plantation, Salters, Constant and Valley Plantation. Assume 6 injection wells will be included in this option	Waterford (to be modelled for impact on nitrates and where the water goes). Treatment using RO is also required to meet irrigation TDS requirements)	9 kms	186 Hectares
4	BSTP to Spring Garden BWRO desalination plant. Assume 3 injection wells will be included in this option	Spring Garden using reclaimed water with reuse water quality. No RO treatment cost is required.	3 kms	None
RO	Reverse Osmosis Treatment Facility	Required for agricultural irrigation use. CAPEX includes additional PV panel costs to offset additional energy requirements. **Does not apply to Option 4**	NA	NA

The Conceptual Design and Feasibility Reports by Integrated Sustainability Consultants Ltd provided capital cost estimates as well as operation and maintenance costs associated with the

[1] Available area, actual irrigated area will depend on water availability.

project components. Further to this, a Baseline Study had been completed which set out the basis for the development of a Financial and Economic Model for the 3R-CREWS project as whole, that is encompassing the upgrading of the Bridgetown and South Coast Sewage Systems. The Baseline Study sets out projections of wastewater inflows into the two treatment plants under different development conditions and considers the available areas of land that could be irrigated. Information was also taken from the MAFS study on the use of treated water for irrigated agriculture particularly with respect to irrigation requirements, net income generated from irrigation and other benefits. The CBA is carried out ex-BSTP that is it does not include the upgrade costs of the Plant that are common across all options.

2.2 Wastewater Volumes

The volumes of treated reclaimed wastewater that can be made available from the Bridgetown Plant depends on the developments that take place within the Bridgetown area such as expansion of the sewage collection system, new developments such as the Hyatt Ziva and other changes such as the impact of climate change on unit consumption rates. These factors and projections are discussed in the Baseline Study and the projections are used in this study.

The flows that can be made available for irrigation are taken as being at 80% of the incoming wastewater flows. The reason for this is that the treated wastewater has to go through Reverse Osmosis treatment to reduce the Total Dissolved Solid concentration to 450 mg/ℓ. Not all the treated wastewater goes through the RO process and what does is blended with the remaining treated wastewater, however, the byproduct is a concentrated brine which cannot be used and this reduces the total available wastewater volume by 20%.

The Model and wastewater flows only consider the demand being based on the assumption that there is sufficient water availability to meet consumptive demand and hence generate wastewater flows. Under these conditions, climate change has the effect of increasing demand and hence wastewater flows.

3. Costs and Benefits

3.1 Capital Costs

The capital cost items included in the analysis are summarised in Table 2 and Table 3.

Table 2: Capital Items

Item	Option 1	Option 2	Option 3	Option 4
Pipelines	13 km	27 km	9 km	3 km
Reverse Osmosis Plant	☑	☑	☑	
Installation of Injection Wells	6 (2 x 3)	9 (3 x 3)	6 (2 x 3)	3 (1 x 3)
Transfer Pump Stations	2	3	2	1
Brine Pump Station	☑	☑	☑	
Reservoir	☑	☑	☑	☑

Table 3: Capital Costs

ITEM	Option I	Option 2	Option 3	Option 4
Pipelines	$6,500,000	$13,500,000	4,500,000	$1,500,000
Reverse Osmosis Plant	$2,000,000	$2,000,000	$2,000,000	
Installation of Injection Wells	$300,000	$400,000	$300,000	$100,000

Pump Stations	$250,000	$350,000	$250,000	$100,000
Reservoir	$240,000	$240,000	$240,000	$240,000
Total	**$9,050,000**	**$16,250,000**	**$7,050,000**	**$1,700,000**

3.2 Operation and Maintenance Costs

The basis for the calculation of the operation and maintenance costs associated with each option are set out in Table 4.

Table 4: Operation and Maintenance Costs

Cost Item	Rate	Units
Pipelines - annual maintenance costs	1%	capital cost
Pump stations - annual maintenance costs	15%	capital cost
Balancing reservoirs - maintenance costs	1%	capital cost
Injections wells - maintenance costs	$10,000.00	per well
Reverse Osmosis -Operation & Maintenance costs	$0.03	US$/m³
Pump stations - power costs per station • Option 1 • Option 2 • Option 3 • Option 4	 0.035 0.055 0.030 0.010	US$/m³

3.3 Benefits

Two benefits arise out of the reuse of the treated wastewater. The first is the sale of the treated wastewater itself to the beneficiaries it is supplied to. The second is the net income that can be generated by the beneficiaries from its use. Both are dependent on the volume of water that can be supplied. In the Cost Benefit model, the sale price of the reused treated water can be varied, which allows the impact of different prices to be explored. With respect to the net income generated from the use of the reclaimed water the MAFS Study provided information on this, which has been used in this analysis.

There is a further point regarding the volume of water required. It is assumed that irrigation water is only required for nine out of twelve months. The rationale for this is that irrigation is required when there is a moisture deficit, when evapotranspiration is greater than precipitation. An examination of future climate projections of aridity for Barbados in 2050 indicates that this will occur for nine months of the year. This argument was discussed and accepted by the Technical Working Group. For times when water for irrigation is not required then the water would be used for Managed Aquifer Recharge utilising the injection wells. The sets of injections wells are at different locations allowing alternative options as to where Managed Aquifer Recharge takes place.

The net farm incomes were calculated based on an assumed net income of Bds$80,000 per irrigated acre. The assumed rate of water application was taken as $50m^3$ per acre per day. Both as per the MAFS Study. This was used to convert net income into a unit amount per m^3.

The MAFS Study also considered additional economic benefits associated with increased job opportunities, multiplier effect on local economies and import substitution. The impact on local economies and import substitution were not costed and were considered as non-quantifiable variables. These additional benefits were not directly quantified in this study but were taken into account as part of the Triple Bottom Line evaluation.

4. Results

4.1 Financial Analysis

In order to carry out the CBA and to incorporate the impact of the Bridgetown development scenarios as well as the assessment of the impact of different variable assumptions e.g. inflation rate, a dedicated CBA Model was developed. The choice variables in the Model included:

- Bridgetown development scenarios.
- Climate scenario
- Inflation rate (%)
- Discount rate (%)
- Water tariff (US$/m^3)
- Wastewater as a percentage of water consumption (%)
- Net volume of wastewater supplied after RO (%)

The outputs from the Model are:

- Total Capital & Operations Net Present Value (US$)
- Net Present Volume of Water Supplied
- Unit cost of water (US$/m^3)
- Net Present Value of Benefits (US$)
- Cost Benefit Ratio
- Internal Rate of Return (%)

The Model was run with the following variable values and outputs. The Baseline Case includes known planned developments for which there are budgets and can be expected to be realised within the next 2-3 years. The scenario assumes a ‘real’ social discount rate which reflects the social preference rate for public projects and RCP4.5. The Standard Case includes all the planned and proposed developments, and hence the maximum number of connections to the wastewater system. All other variables are held constant. Table 7 and Table 8 are sensitivity analyses which consider the impact of more sever climate change and different assumptions around inflation and discount rates. Table 9 investigates the impact an increase in the selling price of reclaimed water supplied.

Table 5: Baseline Case

Input Variables				
Development Scenario	Present & planned up to and including Hyatt Ziva			
Climate Scenario	RCP 4.5			
Inflation Rate	0%			
Discount Rate	3%			
Irrigation Water Tariff (US$/m^3)	0.60			
Results				
Item	**Option1**	**Option 2**	**Option 3**	**Option 4**
NPV Capital and Operational Costs (US$ million)	$17.150	$28.506	$17.621	$3.164
NPV Benefits (US$ million)	$9.825	$51.015	$51.015	$18.273
Cost Benefit Ratio	0.57	1.79	2.90	5.78
Internal Rate of Return	-6%	13%	29%	41%

Table 6: Standard case

Input Variables				
Development Scenario	Present & planned up to redevelopment of the CDB			
Climate Scenario	RCP 4.5			
Inflation Rate	0%			
Discount Rate	3%			
Irrigation Water Tariff (US$/m^3)	0.60			
Results				
Item	**Option1**	**Option 2**	**Option 3**	**Option 4**
NPV Capital and Operational Costs (US$ million)	$17.622	$29.408	$18.483	$3.210
NPV Benefits (US$ million)	$9.825	$58.174	$58.174	$20.838
Cost Benefit Ratio	0.56	1.98	3.15	6.49
Internal Rate of Return	-7%	16%	32%	45%

Table 7: Impact of Climate Change on Standard Case

Input Variables				
Development Scenario	Present & planned up to redevelopment of the CDB			
Climate Scenario	RCP 8.5			
Inflation Rate	0%			
Discount Rate	3%			
Irrigation Water Tariff (US$/m^3)	0.60			
Results				
Item	**Option1**	**Option 2**	**Option 3**	**Option 4**
NPV Capital and Operational Costs (US$ million)	$17.656	$29.474	$18.546	$3.213
NPV Benefits (US$ million)	$9.825	$58.695	$58.695	$21.024
Cost Benefit Ratio	0.56	1.99	3.16	6.54
Internal Rate of Return	-7%	16%	33%	45%

Table 8: Impact of Inflation and Discount Rates on Standard Case

Input Variables				
Development Scenario	Present & planned up to redevelopment of the CDB			
Climate Scenario	RCP 4.5			
Inflation Rate	4%			
Discount Rate	7%			
Irrigation Water Tariff (US$/m^3)	0.60			
Results				
Item	**Option1**	**Option 2**	**Option 3**	**Option 4**
NPV Capital and Operational Costs (US$ million)	$18.663	$31.557	$19.993	$3.475
NPV Benefits (US$ million)	$10.379	$61.462	$61.462	$22.015
Cost Benefit Ratio	0.56	1.95	3.07	6.34
Internal Rate of Return	-1%	20%	37%	50%

Table 9: Impact of a Change in Reclaimed Water Tariff

Input Variables				
Development Scenario	Present & planned up to redevelopment of the CDB			
Climate Scenario	RCP 4.5			
Inflation Rate	0%			
Discount Rate	3%			
Irrigation Water Tariff (US$/m^3)	1.20			
Results				
Item	**Option1**	**Option 2**	**Option 3**	**Option 4**
NPV Capital and Operational Costs (US$ million)	$17.622	$29.408	$18.483	$3.210
NPV Benefits (US$ million)	$20.306	$71.510	$71.510	$43.064
Cost Benefit Ratio	1.15	2.43	3.87	13.42
Internal Rate of Return	6%	20%	40%	77%

The results all demonstrate that Option 4, supplying treated water for Indirect Potable Recharge to the Spring Garden Brackish Water Desalination Plant would be the preferred option in terms of financial indicators and Option 1 the least favourable. The reasons are reasonably obvious, the capital and operational cost associated with Option 4 are low in comparison with the other options even though the only benefits derived are from the sale of treated wastewater. However, because the water does not have to go through Reverse Osmosis treatment, this option generates higher volumes of water

Option 1 is the least favourable because of the relatively high capital and operation costs and the more limited volume of water that would be sold. This option does not include any benefit from farm income. Option 2 is the next least favourable, again on account of the high capital and operational costs. A feature of both Options 2 and 3 is that the Benefits are the same. The reason for this is that it is the volume of reclaimed water that is the limiting factor, there is more land available than available water to irrigate it.

In terms of the sensitivity analyses, moving from RCP4.5 to RCP8.5 increases water consumption and hence increases wastewater flows and thus, under conditions of unconstrained water supply, it has a positive effect on wastewater flows and on the benefits generated, being greater than the additional costs associated with the pumping of greater volumes of water to irrigation. Increases in both inflation and discount rates result in an increase in the net present value of both costs and benefits. Overall the effect is to increase the costs more than the increase in benefits resulting in poorer financial performance. As expected, increasing the selling price for reclaimed water improves the financial indicators across the board as it increases the net present value of benefits whilst there are no additional associated costs.

The result of the financial analysis clearly demonstrate that there are strong grounds for adopting Option 4.

4.2 Triple Bottom Line Analysis

In discussing the results of the financial Cost Benefit Analysis with the Technical Working Group, it was indicated that as was done for the South Coast Prefeasibility Study, a Triple Bottom Line approach should also be undertaken. This was to ensure that equal weight was given to non-financial factors in recommending the preferred option. In the Triple Bottom Line approach, the financial CBA would be but one of the factors to be considered.

A Triple Bottom Line Matrix was developed based on the approach used in the aforementioned Prefeasibility Study but adapted to suit the circumstance of the Bridgetown Plant and the options it could supply. The three categories of factors were Social, Environmental, and Financial and Economic Factors. Under each of these a long list of sub-categories were developed for consideration, which following discussions with the Technical Working Group were narrowed down to those shown in Table 10. As shown in the Table, each category was assigned an individual total weight of 20. The weightings of the sub-categories were decided up by consensus among the Technical Working Group members.

Having agreed on the individual sub-category weightings, the Technical Working Group then went through each of them for each Option to discuss and agree on the score to be allocated. The outcome of scoring agreed upon by the Technical Working Group is shown in Table 10 below.

Table 10: Triple Botton Line Assessment

			Options 1		Option 2		Option 3		Option 4	
Potable Aquifer Recharge Location			Upstream of Spring Garden or Trents		Upstream of Spring Garden or Trents		Upstream of Spring Garden		Upstream of Spring Garden	
Non-potable Aquifer Recharge Location			Potential indirect recharge from infiltrated irrigation water to the Belle Aquifer		Potential indirect recharge from infiltrated irrigation water to the St Lucy Aquifer		Potential indirect recharge from infiltrated irrigation water to the Belle Aquifer		None	
Food Crop Irrigation Location		Weighting	None		Spring Hall Land Lease, St Lucy		Lears, Neils, Waterford, Salters, Constant		None	
Social Factors (20)	Potential Health Risks (Regulatory Compliance	5	Designed to meet requirements	5	Designed to meet requirements	5	Designed to meet requirements	5	Designed to meet requirements	5
	Food Security (Additional Agricultural Expansion)	5	Addresses the need for water	4	Addresses the need for water	5	Addresses the need for water	4	Does not address food security	0
	Increases potable water supply	5	Does not increase potable water supply	3	Does not increase potable water supply	4	Does not increase potable water supply	5	Increases potable water supply	5
	Increased Employment Opportunities	5	Addresses employment opportunities in agriculture	4	Increases employment opportunities in agriculture	5	Increases employment opportunities in agriculture	4	Secures employment in other sectors indirectly	2
Environmental Factors (20)	Reduced Impacts to Marine Environment	5	Reduces impact on marine environment through groundwater flows. Generates brine at BSTP.	5	Reduces impact on marine environment through groundwater flows. Generates brine at BSTP.	5	Reduces impact on marine environment through groundwater flows. Generates brine at BSTP.	5	Reduces impact on marine environment through groundwater flows. Generates brine.	5
	Groundwater Impacts (Quantity and Quality)	5	Provides augmentation to aquifer, potentially improves water quality, may reduce drawdown and pumping	3	Provides some augmentation to aquifer, potentially improves water quality, may reduce slightly drawdown and pumping	4	Provides some augmentation to aquifer, potentially improves water quality, may slightly reduce drawdown and pumping	5	Provides augmentation to aquifer, potentially improves water quality, may reduce drawdown and pumping	5
	Ecological Impact	5	Potentially positive	5	Some potential	4	Some potential	4	Neutral	1
	Increased GHG Emmissions	3	Next highest increase in power consumption	1.8	Highest increase in power consumption	1.2	Next lowest increase in power consumption	2.4	Lowest increase in power consumption	3
	Increased Agro-chemical use	2	Increase in agro-chemical use linked to area under cultivation	1.2	Increase in agro-chemical use linked to area under cultivation	1.2	Increase in agro-chemical use linked to area under cultivation	1.2	None	2
Financial Factors + Economic Factors (20)	Relative Capital Costs	4	x5.48	2.4	x8.69	1.6	x4.6	3.2	1	4
	Relative Operational Costs	4	x2.51	2.4	x4.66	1.6	x2.17	3.2	1	4
	IRR	4	-3%	0.8	18%	2.4	37%	3.2	48%	4
	Import Substitution	4	Very limited	3.2	Some	3.2	Some	3.2	None	0
	Increased Economic Activity	4	Some potential increase	3.2	Increased economic activity in agricultural sector	3.2	Increased economic activity in agricultural sector	3.2	Supports existing economic activity of non-domestic sectors through security of supply	1.6
	Total			44		46.4		51.6		41.6

The result of Triple Bottom Line assessment is that Option 3 had the highest overall score, whilst Option 4 came out with the lowest score. In other words, Option 4 would make the least contribution out of the four options to social, environmental and economic development of the country. In contrast, Option 3 was judged to have the gretest potential for contributing to Social, Environmental and Economic well-being.

5. Recommendation

Judged purely on the basis of financial Cost Benefit Analysis Option 4 – the supply of treated wastewater to the Spring Garden Brackish Water Desalination Plant, would be the preferred option as it would maximise the financial benefits to the country. Investments in the other options considered, which would support the use of treated wastewater for irrigation would enable a range of non-financial benefits. Given that the 3R-CREWS project is an investment in the future of Barbados it is apposite that these factors should be taken into consideration in decision-making. This was undertaken through the application of a Triple Bottom Line approach. The outcome of this assessment is that the preferred option would be Option 3 – the supply of treated reclaimed wastewater to support irrigation developments in the Codrington-Neils-Lears-Salters-Constant-Valley areas.

In motivating and recommending this Option, the Technical Working Group stressed that this should be seen as a first Phase of a larger enterprise to extend and expand the use of treated reclaimed wastewater for irrigation purposes on lands along the west coast of Barbados and up to the parish of St Lucy. Such a development could incorporate decentralised wastewater treatment facilities along the route which would contribute additional wastewater flows. Furthermore, they noted that such a phased development would also support Managed Aquifer Recharge utilising treated reclaimed water not required for irrigation.

Based on the assessment presented in this document, the Technical Working Group recommends the adoption and incorporation of Option 3 into the 3R-CREWS project.