Orange Walk Sanitation System

Preliminary Viability Study for Collection and treatment alternatives

Belize

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The GEF CReW+ is a partnership project funded by the Global Environment Facility (GEF) that is being co-implemented by the Inter-American Development Bank (IDB) and the United Nations Environment Programme (UNEP) in 18 countries of the Wider Caribbean Region (WCR).

This project builds upon its previous successful phase "The Caribbean Regional Fund for Wastewater Management (CReW)" project (2011-2017). CReW+ is being executed by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the Organisation of the American States (OAS) and the Secretariat of the Cartagena Convention (CAR/RCU) on behalf of the IDB and UNEP respectively.

The 18 participating CReW+ countries (Barbados, Belize, Colombia, Costa Rica, Cuba, Dominican Republic, Grenada, Guatemala, Guyana, Honduras, Jamaica, Mexico, Panama, Saint Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, Suriname and Trinidad and Tobago) vary geographically from large, continental countries to small island states, with significantly different political, linguistic and cultural contexts.

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Abbreviations

BAF	Biological Aerated Filters
BOD	Biological Oxygen Demand
BSI	Belize Sugar Industry
BWS	Belize Water Services Limited
CReW	The Caribbean Regional Fund for Wastewater Management
DOE	Department of the Environment
GEF	Global Environment Facility
GP	Grinder Pump
GPD	Gallons per day
GPM	Gallons per month
LPS	Low Pressure Sewer
OWT	Orange Walk Town
SIB	Statistical Institute of Belize
STEP	Septic Tank Effluent Pump
TW	Treatment Wetland
UN-DESA	United Nations – Department of Economic and Social Affairs
WMS	Wastewater Management Strategy
WWTP	Wastewater Treatment Plant

1. Introduction

The Wider Caribbean Region faces multiple challenges in the provision of wastewater and sanitation services. About 70 percent of the region's population lacks access to safely managed sanitation facilities and adequate hygiene services.

The GEF CReW+ Project "An integrated approach to water and wastewater management in the Wider Caribbean Region using innovative solutions and sustainable financing mechanisms" provides innovative and nature-based solutions to mitigate the effects of partially treated or untreated wastewater on the environment and public health.[1]

As part of its efforts to become a leader in environmental stewardship and in line with national development planning, Belize has strengthened its policy framework. Opportunities to improve water and wastewater management systems across the country through policy, regulatory and financial instruments have been identified. These could help in addressing gaps in service provision, governance and data collection.

The aim of this study is to determine the most viable sanitation solution for Orange Walk Town for a Wastewater Management Strategy (WMS). Therefore, it is important

[1] Source: https://www.gefcrew.org/

to determine the design parameters well and to compare different possible solutions in their applicability in the particular conditions of Orange Walk Town.

The report briefly introduces the specific conditions of Orange Walk Town which impact the requirements a new sanitation system needs to fulfil (Chapter 2). In Chapter 3, data is analyzed to define the design data and specify selection criteria. Chapters 4 and 5 briefly present sewage and treatment options and provide a comparison according to the defined selection criteria. The final Chapter 6 takes the conclusions of the findings and recommends further proceedings.

2. Current situation

2.1 Orange Walk

The Orange Walk District, located on the North of Belize, has an area of 1829 square miles. It is the second largest district in Belize and the second most important population center.

Orange Walk Town is the capital, administrative and commercial center of the Orange Walk District. It is located 53 miles north of Belize City, 30 miles south of Corozal Town, and 43 miles from Chetumal, Quintana Roo, Mexico.

Orange Walk Town is nestled in the fertile land between the New River and the Rio Hondo. The town lies on the west bank of the New River. The Rio Bravo is an extension of the Hondo River. There is a major pond within Orange Walk Town that plays an important role in surface drainage. This has forced the town to expand to the west.

Residents report concern about the health of the river but seem to place the blame principally on commercial activity in the area. The DoE and the Town Council are repeatedly blamed for the poor health of the river.

For the implementation of a WWTP, the community is always a principal stakeholder whose support must be encouraged. In recent years, the New River has been challenged, as reported in local and national media, by symptoms of toxicity including fish kills, unhealthy crocodiles, poor appearance, and bad scent – especially during the dry season. The riparian forest formerly adjacent to the river is largely absent and rumors persist of various commercial agencies including residential houses contributing to the pollution of this important waterway.

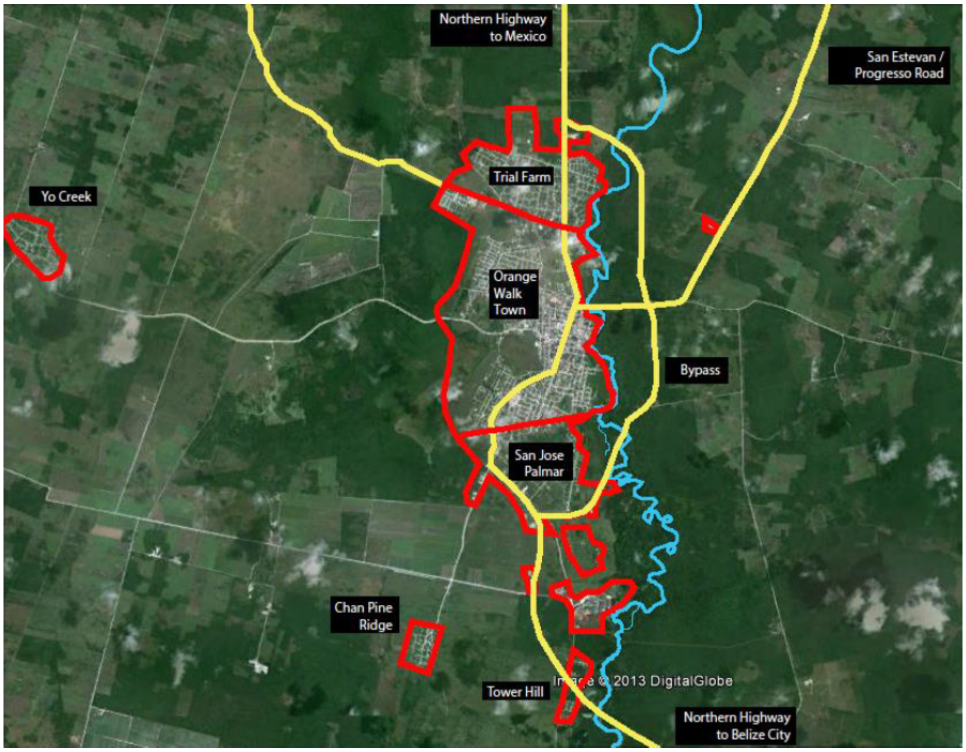
2.2 Population

According to the Statistical Institute of Belize (SIB), Orange Walk Town had a population of 13,709 in 2010. Based on SIB's data, Orange Walk Town population grew from 11,000 to 13,500 in 1991-2000 at an annual growth rate of 2.7% per annum. This growth contrasts with the period 2000-2010 when the recorded figures show population stagnation with a minimum change of only 209 people and an annual growth rate of 0.1%. The national average growth rates for all urban areas during the same period was 2.7% per annum.

There are two villages, namely Trial Farm to the North and San Jose Palmar to the south, which have virtually merged with Orange Walk Town. The Census records a population change in Trial Farm from 3,158 in 2000 to 4,264 in 2010 (equivalent to 3% per annum). San Jose Palmar's population increased from 863 to 1,355 in the same period and expanded at 4.5% per annum.

The low population growth in Orange Walk Town is likely because of population movement from urban to adjacent rural communities such as Trail Farm and San José Palmar.

Figure 1:
Map of surrounding communities



Source: Orange Walk Town / Local Planning Working Group (2015)

2.3 Water provision

Belize Water Services Limited (BWSL) is the national water and sewerage utility in all major urban areas and contiguous villages; it serves all the municipalities of the country, including Orange Walk Town and adjacent villages.

According to the Orange Walk Town Municipal Profile, bottled water continued as the major source of drinking water for households in Orange Walk Town, with the proportion of households using bottled water doubling from 43% in 2000 to 85% in 2010. Table 1 shows the main source of drinking water.

Table 1:
Main source of drinking water

Main source of drinking water	2000		2010	
	Quantity	%	Quantity	%
Total (Households)	2,895	-	3,374	-
Piped into dwelling or yard[2]	702	24.0	247	7.3
Private catchments, not piped	912	32.0	203	6.0
Bottled/purified water	1,236	43.0	2,882	85.4
Other[3]	39	1.0	35	1.0
Not stated	6	0.0	7	0.2

Source: Orange Walk Town Municipal Profile

2.4 Sanitation

According to Orange Walk Town Municipal Profile, flush toilet piped to septic tank is the main type of toilet facility for most households in Orange Walk Town. The Ministry of Health provides guidelines and construction drawings for independent wastewater systems (septic tanks and soaks away). Sludge may be collected from time to time by private contractors who probably dump the waste on private land or on unknown locations. This system appears to be partially controlled by public health inspectors.

[2] Piped into dwelling or yard includes water piped from public and private sources.
[3] Other includes water from dug well and rivers/streams/creeks.

Figure 2:
Wastewater drainage in the Town

Drains contain discolored wastewater with a foul odor. These drains wind to the western boundary of the municipality before emptying into the New River

Source: ©GIZ / AKUT

The proportion of households with flush toilets increased from 61% in 2000 to 80% in 2010. Meanwhile, households using traditional pit latrines have declined by half from 38% in 2000 to 19% in 2010. Orange Walk Town is among the six municipalities in the country without an established sewer system for wastewater disposal and treatment. Table 2 shows the type of toilet facilities.

Table 2:
Type of toilet facilities

Type of toilet facilities	2000		2010	
	Quantity	%	Quantity	%
Total (Households)	2,895	-	3,374	-
W.C. linked to septic tank	1,778	61.4	2,701	80.1
Pit latrine	1,105	38.2	651	19.3
Other	5	0.2	3	0.1
None	4	0.1	12	0.4
Not stated	3	0.1	7	0.2

Source: Orange Walk Town Municipal Profile

Commercial activities that contribute to pollution of the New River include: restaurants, food processing activities, tortilla factories, sugar processing activities and also the town's hospital.

Distillery: The current treatment seems to be only four raised settlement ponds. The Town Council management team report that the 'system' used to be effective, and that the resultant wastewater overflow was then sent through the drains to sugar cane fields where it was used for irrigation. Their understanding is that increased volumes from the distillery have exceeded the capacity of that system, which is no longer viable.

These ponds are also substantially reduced in capacity due to many years of collection of settled solids, assumingly never cleaned. Based on a rough flow rate estimate of the distillery effluent, i.e., 0.25 m^3/sec and the BOD concentration of distillery effluent of about between 40,000 and 50,000 mg/L, the BOD load is 972 kg BOD/day, **which is about five times more that can be expected from the effluent from the residential septic tanks**.

It is not clear where the contaminated waste is discharged and if it has direct influence to the situation of the New River.

Hospital: The hospital has a non-functioning wastewater treatment system on site. The hospital administration has put some 'temporary system' in place to attempt to effect treatment, but it is not clear how effective this is.

Currently a study for a new wastewater treatment for the hospital is under way.

Figure 3:
A drain emptied into the New River

Dead fish and other detritus have been seen where the drains emptied into the New River.

Source: ©GIZ / AKUT

2.5 Potential location for wastewater treatment system

2.5.1 Village expansion

The Annex 6 shows areas for effective urban expansion, in the north in lands adjoining Trial Farm Village on the west, and in the south in land adjoining San Jose Palmar on the west. The land in both cases is high and developable and has a considerable size of several hundred acres.

2.5.2 Drainage

Drainage is complex in Orange Walk. The town is largely located on a watershed - natural drainage flowing east to the New River, and west to the Pico de Agua system, which flows generally north. Two large savannah areas appear to be critical to drainage in the west of the town.

The drainage patterns of the town and its surroundings require in-depth assessment to ensure effective run-off and the avoidance of flooding. It may be proposed that drains in the west of the town are directed either to the savannahs or to the Pico de Agua. Should that be the case, then drainage from the savannahs to the Pico de Agua must be kept open.

2.5.3 WWTP location alternatives

The need for greater information on detailed topography has been identified by most, to plan comprehensive drainage schemes. The Annex 5 indicates the contours generated from Google Earth with which the four main catchment areas could be established.

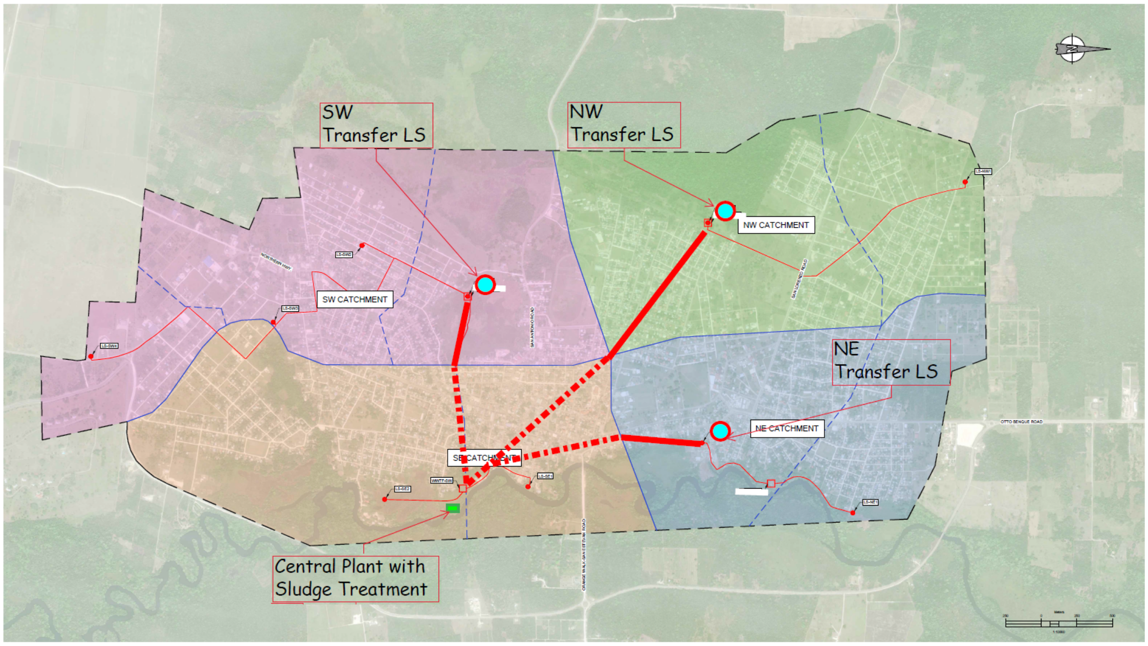
There are several alternatives for the location of the WWTP, which will also depend on the strategy to be implemented, whether one centralized facility or several decentralized ones.

2.5.3.1 Centralized Treatment Facility

Implementing this strategy would require one location which would result in the lowest height for pumping from the other drainage areas and in the minimum cost (capital as well as O&M). The lowest elevation in the Town is in the SE quadrant (Figure 4).

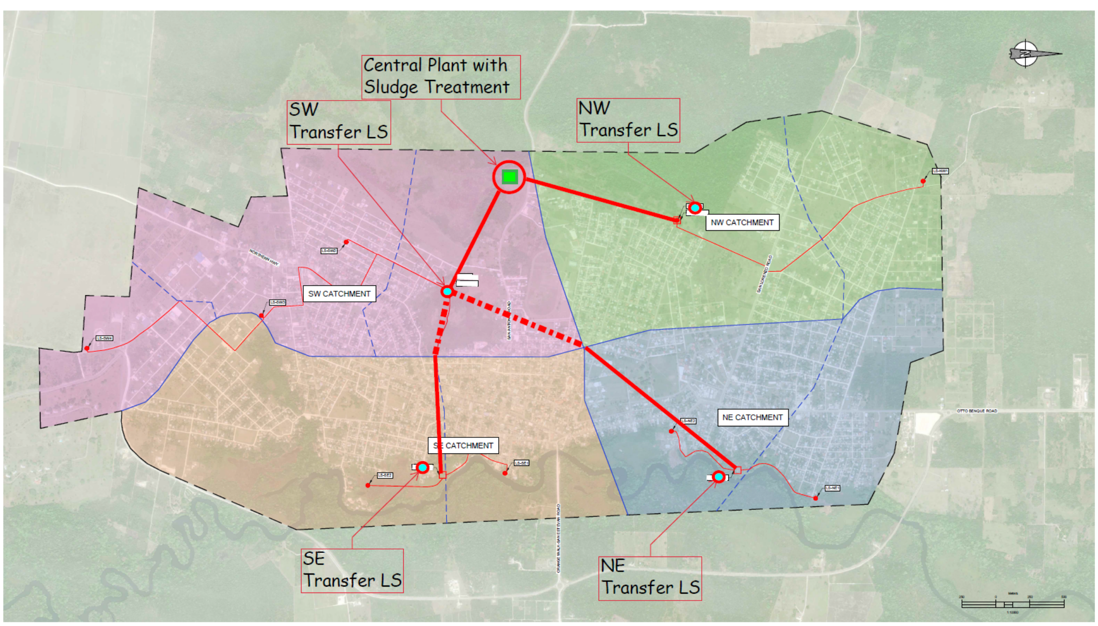
Should it be a requirement to move away from the river and/or other environmental considerations for example, not to be near residential areas, implementing this option will require a location in the SW or NW quadrants (Figure 5).

Figure 4:
Centralized treatment facility - SE



Source: ©GIZ / AKUT

Figure 5:
Centralized treatment facility - SW

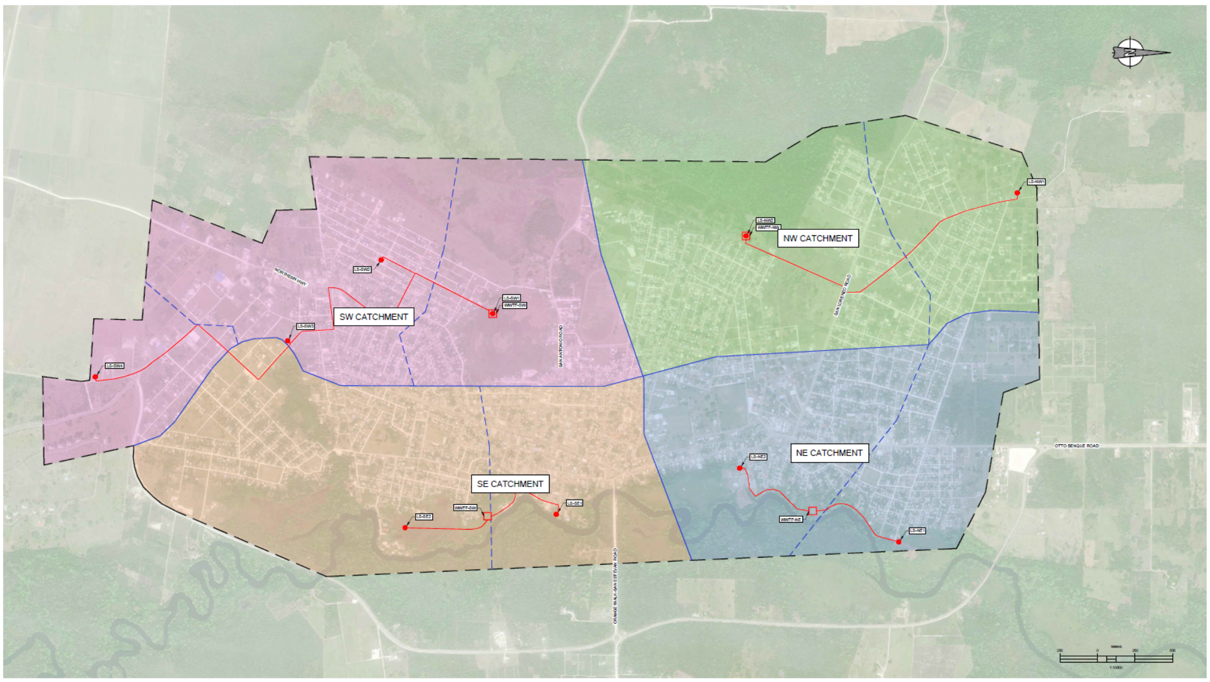


Source: ©GIZ / AKUT

2.5.3.2 Decentralized treatment facilities

Another option could be to design four independent WWTFs. These would serve four distinct drainage basins.

Figure 6:
Decentralized treatment facilities



Source: ©GIZ / AKUT

3. Design parameters and selection criteria

3.1 Effluent standards parameter

The treated effluent in Orange Walk must comply with the standard for discharge in Class 1 waters of the Environmental Protection Regulation of Belize from 2009. This standard defines effluent quality as follows in Table 3.

Table 3:
Effluents standards for the Wastewater Treatment according to the Environmental Protection Regulation

Parameter	Standard
TSS - Total Suspended Solids	30 mg/l
BOD_5 - Biochemical Oxygen Demand	30 mg/l
pH	5 - 10 pH units
Fats, Oil and Grease	15 mg/l
Fecal Coliform	200 mpn/100 ml
Floatable	Not visible

Source: ©GIZ / AKUT

The Project has a design horizon of 20 years; the construction is proposed in two stages. The division is proposed to avoid infrastructure which will not be used adequately for many years. The evaluation of alternatives will refer to the first phase. The population projection will be taken as a basis for calculating the volumes of residual water.

Based on the population projection (3.2.2) and consumption estimate the following values are recommended for the design of the system:

+ Consumption in residential areas: 107.32 GPD (Gallons per Day) per household

+ Rate of return: 80% of drinking water consumption is returned as wastewater
+ Household size: 4.1 p.e. (person equivalents)
+ Population growth: 1.63% p.a. (per annum)

Table 4 shows the projected wastewater volumes for 2023, 2033 and 2043, with a total volume of 618,124 GPD in 2043. The wastewater projection per year is provided in Annex 1.

Table 4:
Projection of wastewater volume [GPD]

Year	Volume [GPD]
2023	447,081
2033	525,707
2043	618,124

Source: ©GIZ / AKUT

3.2 Influent parameters

3.2.1 Raw water loads

Table 5 demonstrates the typical raw water parameter per p.e person equivalent which should be used if there is no better reference. In the case of Orange Walk, the consultants did not encounter a better or more accurate source to analyze the raw water load to the treatment plant.

Table 5:
Projection of wastewater load per capita

Parameter	Load	
	Value	Unit
BOD_5	50	g/pe.d
COD	100	g/pe.d
SST	60	g/pe.d
TKN	8	g/pe.d
P_{TOT}	1	g/pe.d
Total Coliforms	10^{10} - 10^{13}	org/pe.d

Source: Table 2.24 in Von Sperling (2007)

Not much information is available on wastewater generation by commercial and industrial businesses. An in-depth evaluation will however be necessary during the following stages following the findings and recommendations of this preliminary study.

3.2.2 Population projection (residents)

The number of inhabitants of Orange Walk Town is not officially registered for 2023. However, there are two available population projections for Belizean urban areas – those provided by SIB and by the World Bank study. The results are similar, the information based on SIB will be used.

3.2.2.1 Statistical Institute of Belize

- According to SIB, the population Orange Walk Urban and the villages close by are:
- 1980: 8,439
- 1991: 11,014
- 2000: 13,572
- 2010: 13,709

The annual growth rates are 2.45% (1980 - 1991), 2.35% (1991 - 2000) and (2000 - 2010) 0.1%; an average 1.63%.

Table 6 shows the projected population for 2030, 2033 and 2043, with a total population of 23,396 in 2043. The population projection per year is provided in Annex 1.

Table 6:
Population projection (residents) by SIB

Year	Residents	Growth rate (%)
2023	16,922	1.63%
2030	18,954	1.63%
2033	19,898	1.63%
2043	23,396	1.63%

Source: ©GIZ / AKUT

Official information on the average household size is not available for Orange Walk Towm. According to the censuses, the average household size was 4.4 persons per household in 2000 and 4.1 person per household in 2010.

3.2.2.2 World Bank study

The World Bank growth projections of individual cities/town are based on United Nations Population Division (UN-DESA) for Belize in 2020 – 2050. The total number of urban residents in all cities/towns in a given year was constrained to equal the projected total urban population in that year. Then, the added population to a given municipality was assumed to be proportional to the average of three values: the population that was added to the municipality between 1991 and 2000, the population that was added to the municipality between 1980 and 2000, and the population that was added to the municipality between 1970 and 2000.

**Table 7:
Population projection (residents) by World Bank study**

City	2010	2020	Annual Change (%)	2030	Annual Change (%)
Orange Walk	13,400	17,538	2.7%	20,518	1.6%

Source: The World Bank (2011)

3.3 Selection criteria

The selection criteria to be considered in the prioritization of the sewer system and the wastewater treatment system are based on criteria that refer to the topographic conditions of Orange Walk Town, investment and operating costs, as well as the complexity of the system for operation and maintenance.

3.3.1 Selection criteria for sewer system

The first three selection criteria are related to the topography of Orange Walk Town and can be considered exclusion criteria.

+ **Drainage.** The natural drainage flowing to two basins, east to New River and west to the Pico de Agua.

The following two criteria refer to the cost for implementation and operation of the system and inform about the financial feasibility of the system.

+ **Capital expenditure.** The capital expenditure (CAPEX) is the base for calculating the cost-effectiveness of any system. The CAPEX per capita can be especially high for small communities, such as Orange Walk Town.

- **Operating expenditure.** The operating expenditure (OPEX) include costs for operation and maintenance (e.g., energy, replacement parts and staff).
    - **Electricity.**
    - **Number of operators.**
    - **Maintenance costs.** Costs for spare parts and repairs by contracted firms.
    - **Cost for sludge removal from septic tanks.**

The complexity of the system directly influences its operational sustainability.

- **Complexity of the system.** The higher the complexity of the system, the greater the potential for long down-times in case of failure. Aspects to be considered:
    - **Availability of spare parts and service providers.**
    - **Level of training (operators).** The required level of training of operators influences the OPEX. The availability of sufficiently skilled operators may be a restrictive factor.

The remaining three criteria are related to the interaction of the homeowner or customer. Any responsibility outsourced to the customer lacks immediate controllability by the operator and thus proves a potential risk to the reliability of the system. Therefore, in general systems that do not require the customer for operation and maintenance are to be prioritized.

- **Homeowner (customer) training requirement.** Complex systems that require the involvement of the customer in operation and maintenance may entail specific training. Preference should be given to systems that do not require customer involvement.
- **Private property access.** Private property access can be critical for installation but also for operation and maintenance of sewer systems. Therefore, preference should be given to systems which do not require access to private properties

3.3.2 Selection criteria for Wastewater treatment system

The first three selection criteria are related to the development of Orange Walk Town and can be considered exclusion criteria.

- **Land requirement.** Every treatment system must be checked for its applicability in each case. Especially, natural systems must be analyzed critically due to their higher land requirement.
- **Flexibility to hydraulic and organic load peaks.** It is useful to apply systems with a very high flexibility regarding hydraulic and organic load peaks. Natural systems and SBR systems have an advantage here.
- **Vector and odor problem.** The wastewater treatment system will be installed in relative proximity to residential areas; therefore, the proliferation of vectors and formation of odors should be prevented as far as possible.

The complexity of the system directly influences its operational sustainability.

- **Complexity of the system.** The higher the complexity of the system, the greater the potential for long down-times in case of failure. Aspects to be considered:
    - **Availability of spare parts and service providers.** Belize does not have an expressive sanitation market; therefore, most specialized maintenance must come from abroad. To guarantee a robust system, it is recommended to limit requirements for specialized maintenance. Spare parts for critical equipment should be stored to maintain the plant in operation without breakdowns.
    - **Level of training (operators).** The required level of training of operators influences the OPEX. The availability of skilled operators may be a restrictive factor.

- **Primary Treatment.** The primary treatment is a critical aspect in regard permanent operation and sludge production. A system without a permanent need for raw sludge handling should be chosen.
- **Sludge Generation.** The sludge handling is often a critical aspect in the operation of wastewater treatment plants. Systems which generate a constant need for sludge removal from the plant are not recommended, as they would cause significant operational costs.
- **Automation.** To have a relatively low need for operation it is recommended that the plant should be automated, but due to the criteria of skill level this automation should be kept as simple as possible.

3.3.3 Estimation of the total sewer length

Based on google Earth a rough estimation of the total length of the sewer has been carried out. The length of the sewer will be about 124.000 m and a number of pumping stations will be necessary due to the topography. The final length depends on the chosen sewer solution.

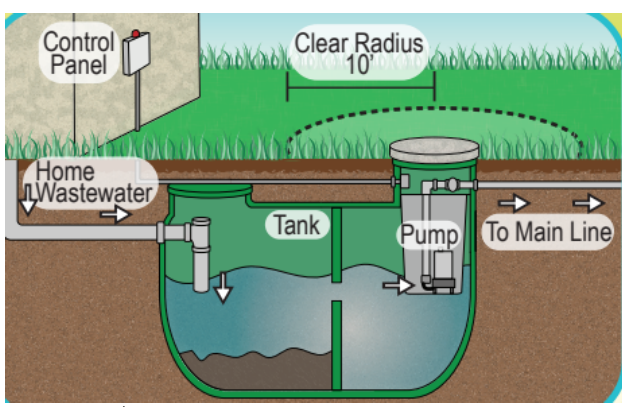
4. Sewer: Comparison of options

+ As discussed in section 2.5.2, the OWT drainage flows east to the New River. Due to its complex and sensitive environmental concerns, the consultants propose two different systems:
+ Low Pressure Sewer (LPS)
+ Gravity sewer and pumping systems
+ As these systems are not standard systems, their general setup and design criteria will be briefly presented in the following sections, before comparing the options.

4.1 Low Pressure Sewer (LPS)

+ Low pressure sewer (LPS) systems are an effective method to move residential wastewater through small diameter pipes to collection facilities. They include grinder pump, septic tank effluent pump, and vacuum systems and can offer cost-effective wastewater conveyance solutions in areas where traditional gravity sewers are not feasible or are expensive to install.

Figure 7:
Low Pressure Sewer



Source: Charlotte Country Government[4]

[4] Link: https://www.charlottecountyfl.gov/core/fileparse.php/523/urlt/lps-brochure.pdf

Design principles for low pressure sewer

- Two major types of pressure sewer systems are the septic tank effluent pump (STEP) system and the grinder pump (GP). Neither requires any modification to plumbing inside the house.
- In STEP systems, wastewater flows into a conventional septic tank to capture solids. The liquid effluent flows to a holding tank containing a pump and control devices. The effluent is then pumped and transferred for treatment.
- In a GP system, sewage flows to a vault where a grinder pump grinds the solids and discharges the sewage into a pressurized pipe system. GP systems do not require a septic tank but may require more horsepower than STEP systems because of the grinding action
- Depth: Minimum coverage to prevent physical damage, where possible the consultants recommend at least 70 cm
- Diameter: 100 mm (4")

4.2 Gravity sewer and pumping system

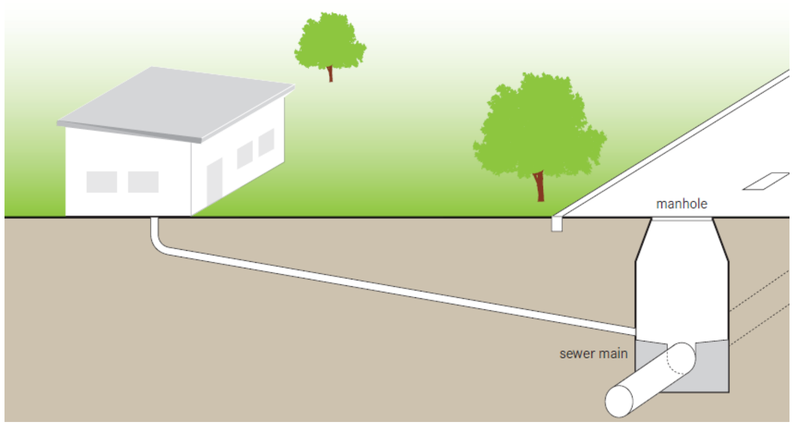
Conventional Sewers are large networks of underground pipes that convey blackwater, greywater and, in many cases, stormwater from individual households to a (Semi-) Centralized

Treatment facility, using gravity (and pumps when necessary).

Gravity sewers normally do not require onsite pre-treatment, primary treatment or storage of the household wastewater before it is discharged. Primary sewers are laid beneath roads, at depths of 1.5 to 3 m to avoid damages caused by traffic loads.

Access manholes are placed al set intervals above the sewer, at pipe intersections and at changes in pipeline direction.

Figure 8:
Gravity sewer



Source: Reuter (2022)

Design principles for gravity sewer

The gravity sewer system is designed to ensure a minimum self-cleansing velocity. Therefore, it requires a minimum gradient of 1%, thus showing the same limitation as a conventional gravity sewer, requiring a sufficient slope:

+ Depth: 1.50 m
+ Tractive tension: 1 Pa
+ Gradient: 1%
+ Diameter: 150 mm (6")

4.3 Comparison of sewer options

The technical comparison of the two sewer options is based on the selection criteria in section 3.3.1. In summary it can be stated that both possibilities are to be studied based on the topography. Regarding the remaining selection criteria, the two options show varying strengths and disadvantages. Details are discussed in the following text.

The primary differences between conventional gravity sewer systems and LPS systems are in the piping network and the reduction of solids size in the wastewater. Low pressure sewer systems typically use submersible grinder pumps, which are designed to reduce sewage particulate size to easily move the sewage through small diameter pipes.

LPS systems are designed to serve individual or multiple properties and are frequently installed with the understanding that the property owner would be responsible for maintaining the system (which can thus be less expensive than conventional gravity systems).

Retrofitting existing septic tanks in OWT seems not to be an opportunity for cost savings, as a large number (perhaps the majority) would need to be replaced or expanded over the life of the system because of insufficient capacity, deterioration of concrete tanks, leaks, or incorrect construction in the first instance.

LPS systems are most cost effective where housing density is low, where the terrain has undulations with relatively high relief, and where the system outfall must be at the same or a higher elevation than most or all the service area. They can also be effective where flat terrain is combined with high ground water or bedrock, making deep cuts and/or multiple lift stations excessively expensive.

LPS systems have low front-end investment making the present-value cost of the entire system lower than that of conventional gravity sewerage, especially in new development areas where homes are built over many years. Because wastewater is pumped under pressure, gravity flow is not necessary and the strict alignment and slope restrictions for conventional gravity sewers can be relaxed. Network layout does not depend on ground contours: pipes can be laid in any location and extensions can be made in the street right-of-way at a relatively small cost without damage to existing structures.

Another advantage of LPS, material and trenching costs are significantly lower because pipe size and depth requirements are reduced. Low-cost clean outs and valve assemblies are used rather than manholes and may be spaced further apart than manholes in a conventional system. Infiltration is reduced, resulting in reductions in pipe size. The user pays for the electricity to operate the pump unit.

Among the disadvantages to LPS system are that they require much greater institutional involvement because the pressure system has many mechanical components throughout the service area. The operation and maintenance (O&M) cost for a pressure system is often higher than a conventional gravity system due to the high number of pumps in use. Annual preventive maintenance calls are usually scheduled for GP components of pressure sewers.

STEP systems also require pump-out of septic tanks at two-to-three-year intervals. The fecal sludge has to be treated in a centralized system. Furthermore, public education is necessary, so the user knows how to deal with emergencies and how to avoid blockages or other maintenance problems.

In total it seems to be that for the general situation, a conventional gravity system is the best option. It seems to be that an LPS system could be an interesting option for the outer areas in a second phase of installing a wastewater collection system for Orange Walk Town.

5. Wastewater treatment: Comparison of options

As discussed in section 2.5, the options for wastewater treatment include technical and natural options. As a general rule, the more technical the treatment, the smaller the required area. However, the more technical treatment options require more operation and maintenance activities. The performance of natural systems is minimally influenced by operational measures. As a consequence, they must be very carefully designed.

As alternatives, the consultants propose two different systems:

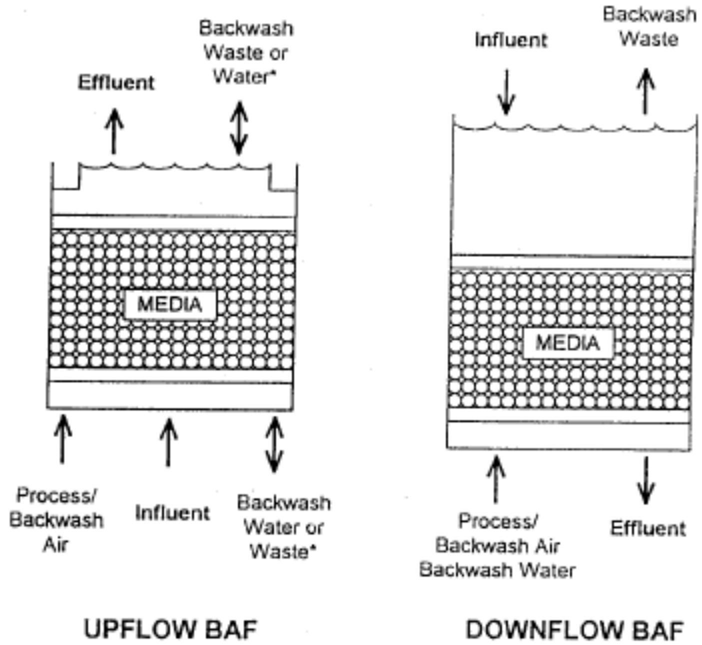
+ Biological aerated filters
+ Treatment wetland – French system

5.1 Biological aerated filters (BAF)

Biological aerated filters are up-flow, down-flow, and fluidized bed reactors with fixed or moving media that do not use secondary clarification. This option seems especially interesting as there is currently experience in Belize with the system.

The unique advantage of the submersed attached growth system is the small footprint required with an area requirement that is a fraction (1/5 to 1/3) of that needed for activated sludge treatment. Other advantages compared to activated sludge are the ability to handle dilute wastewater and the avoidance of activated sludge settling concerns. In addition to BOD removal, submersed attached growth processes have also been used for tertiary nitrification and denitrification following suspended or attached growth nitrification.

Figure 9:
Schematic of upflow and downflow biological aerated filters



Source: Mendoza-Espinoza and Stephenson (1999)

- The Biological Aerated Filter (BAF) falls within a broader term for these types of systems which is a biological activated filter. The up-flow configuration is preferred because the trapping of rising air in the downflow operation mode could result in undesirable increased head loss in the downflow BAF which led to the preferred up-flow BAF designs. Factors that distinguish the different designs are:
- The flow direction – upflow or downflow
- Media density
- Media size
- Media material
- Media depth
- Fluid velocity
- The method used for solids removal

- No clarification is used with aerobic submersed attached growth processes and excess solids from biomass growth and influent suspended solids trapped in the system must be removed periodically. Most designs require a backwashing system much like that used in a water filtration plant to flush out accumulated solids usually daily. The BAF processes can produce effluent BOD and TSS concentrations of <10mg/L for secondary treatment. The up flow BAFs are more popular due to their lower and more reliable head loss but they may require a higher amount of product water for backwashing. Spent backwash water is returned to the headworks prior to primary settling tanks. Recycle of backwash water to the primary treatment step is thought to improve BOD removal in primary treatment due to adsorption of BOD by the BAF waste biomass. In this system, separate sludge treatment is required.

5.2 Treatment wetland (TW) – French system

The so-called **French Filter** has revolutionized the concept of communal wastewater treatment in France and other European countries since the 1990s. Currently more than **4.000 French Wetland Systems** are being used in France only attending population ranges from 200 to 6,000 person equivalents.

The "**Classical" French Wetland System** combines the **"French Filter" as 1. Stage for raw wastewater treatment** with a **vertical sub-surface flow wetland as 2. Stage** (Figure 10). The need for two stages is due to the cold **climatic conditions** in combination with advanced treatment demands. Therefore, **vertical flow sub-surface wetlands** were used in Europa already before the development of the ***French Wetland System***, especially because of their high nitrification potential, but as secondary treatment, according to Figure 11, it was previously dependent on classic pre-treatment technologies with own needs on design and own challenge of maintenance.

The **French Wetland System** solved this obstacle in an exemplary way: **replacing**

classic pre-treatment technologies with a French Filter, a Wetland with a very **high efficiency in retaining and degrading suspended solids and organic matter of raw wastewater** (primary sludge). This sludge, retained on the surface is **degraded by strictly aerobic processes (oxidation)**, without odor or release of Greenhouse gases and without need for manipulation. The dry product can pile up to a height of 15 to 20 cm before it needs to be removed, which lasts 10 years or more.

As mentioned before, the "Classical" French Wetland System (Figure 10) is composed of:

- **1. Stage: French Filter.** Composed of three separate areas with gravel as filter material for the retention of solids on its surface and biological activated filtration with DBO/COD removal of the effluent.
- **2. Stage: Vertical sub-surface flow wetland.** Typically divided into two areas, with coarse sand as filter material, to complete removal of organic matter and nitrification of the pre-treated effluent.

Figure 10:
Treatment wetland (TW) – French system[5]

Source: ©GIZ / AKUT

[5] Letf: WWTP for 800 inhabitants in Spain; 1. Stage with three areas for the treatment of raw wastewater and 2. Stage with two areas mainly for the nitrification of the pre-treated effluent. Right: Pilot wetland plant at UNALM University in Lima/Peru (background) and cones of raw waste water, effluent of 1. Stage and effluent of 2. Stage of the Classic French System (foreground).

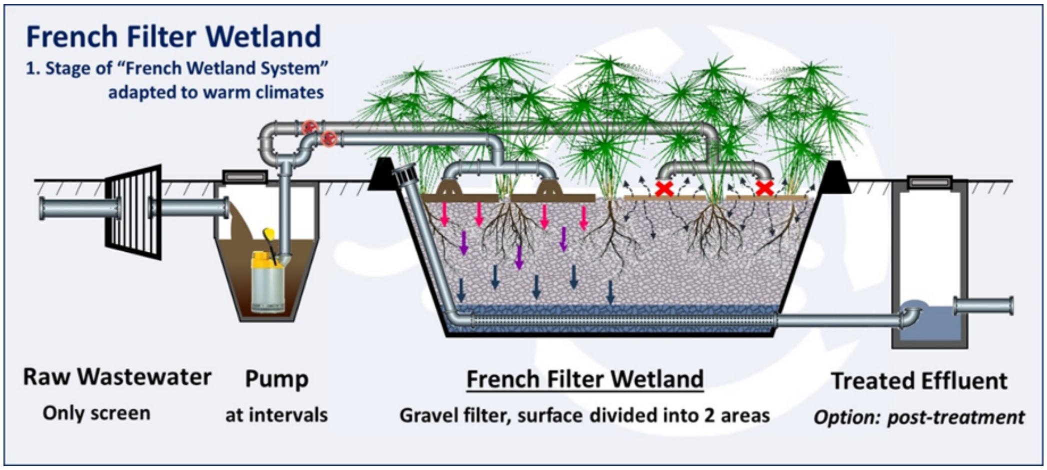
Since 2000, the concept of the **French Wetland System** was introduced and researched in **warm climates**, including Caribbean states[6], Brazil[7] and Peru[8]. The investigations in **warm climates show a much higher potential of the first Stage,** which allows subsequent adaptation of the concept**:**

- The efficiency of the first Stage reaches 80 to 90 % COD/BOD removal, and the nitrification process occurs partially. That means that in a warm climate conditions the French Filter as single stage already meets highest treatment requirements.
- Where even higher effluent treatment efficiency is required, post-treatment can be guaranteed by less sophisticated technologies such as horizontal flow sub-surface wetlands or maturation pond, depending on the treatment objective.
- Regarding the treatment of raw wastewater sludge, the warm temperatures allow its accelerated decomposition. This means, that the sludge needs less rest time for stabilization, allowing to use only two instead of three areas (33% reduction in area).

According to the studies cited, the **adaptation of the first Stage** of the classic French Wetland System with a comparatively smaller area (2 instead of 3 areas) was **effective for single stage treatment of raw wastewater in warm climates** (80 - 90% COD and TSS removal and partial nitrification) and at the same time **primary sludge is co-treated**. Figure 11 shows the layout of such **French-Filter as single stage.**

[6] French IRSTEA Institute (Prof. Pascal Molle).
[7] UFMG University (Prof. Marcos von Sperling).
[8] UNALM University (Prof. Rosa Miglio).

Figure 11:
French Wetland System (schematic)[9]



Source: ©GIZ / AKUT

As shown in the Figure 12 the **primary sludge is treated on the first stage by natural aerobic decomposition, somewhat comparable with a compost system.**

Figure 12:

French Wetland System – treatment of raw sewage solids[10]

Source: ©GIZ / AKUT

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[9] Approved as a single stage of raw wastewater treatment in a warm climate conditions, divided into two areas, ensuring frequent surface rest and complete drying and mineralization of deposited sludge.
[10] Intermitted use of two beds in a rate of two to four days allows for complete aerobic decomposition.

Finally, it is important to mention that **emerging plants or macrophytes**, species adapted to the climate and conditions of abundance of water and nutrients, grow very quickly and **after a few weeks of initiation of the process cover completely the surface of the filter and the discharge points** (Figure 13).

Figure 13:

French Wetland System – species of macrophytes[11]

Source: ©GIZ / AKUT

In accordance with the cited studies and the growing worldwide demand on nature-based sanitation solutions, **the French-Filter is seen currently as one of the most promising treatment technologies for raw wastewater in warm climate conditions**, because of the **extremely low operating costs** and **very high and stable treatment performance, including efficient effluent and sludge treatment**. For the case of Orange Walk Town, a conservative number for dimensioning the treatment is 1.8 m² /p.e.

[11] French Filter to treat the raw sewage in Florianópolis / Southern Brazil with different species of macrophytes and after 3 months of operation.

5.3 Comparison of wastewater treatment options

The Centralized Treatment Plant with Wetlands offers several advantages that make it an appealing option. Firstly, by consolidating all treatment processes into a single location, it simplifies the overall system, leading to fewer challenges related to population distribution and operational management. This streamlined approach reduces potential issues and ensures a more efficient and effective treatment process.

Another notable advantage of the centralized plant with a wetland is the direct treatment of fecal sludge on the beds without the need for additional treatment steps. This integrated approach eliminates the requirement for extra processes, saving time and resources. It also enhances the overall treatment efficiency, effectively removing contaminants and improving the quality of treated wastewater. By avoiding the need for additional treatment steps, the operational costs of the centralized plant may potentially be lower than those of having four separate treatment plants, although this aspect requires further study to determine the exact cost-effectiveness.

However, it is important to consider the space requirement of the centralized treatment plant. With an approximate need of 1 m^2 per population equivalent (p.e), a considerable amount of land is necessary to accommodate the treatment plant and wetland beds. This could be a significant drawback in areas where space is limited or costly. The trade-off between the advantages and the space requirement must be carefully assessed before making a decision.

On the other hand, the four decentralized plants present their own set of advantages. By eliminating the need for extensive pumping stations, this decentralized approach simplifies the infrastructure and reduces associated maintenance costs. The smaller-scale treatment facilities can be strategically located closer to the source of wastewater generation, minimizing the need for pumping. This results in operational efficiency and potentially reduces energy consumption compared to a centralized system.

Moreover, the decentralized plants offer a compact footprint for treatment. Their smaller design allows for efficient land utilization, making them suitable for areas where space is limited or where the cost of land is high. Additionally, the treatment process in the decentralized plants includes aerobic stabilization of the sludge, ensuring the complete handling of the septage sludge and further improving the overall treatment efficacy.

However, it is crucial to conduct a comprehensive analysis to fully evaluate the viability of the decentralized option. Factors such as total investment costs must be carefully examined. Initial indications suggest that the decentralized approach, with its requirement for duplicating treatment infrastructure, may incur higher costs compared to the centralized plant.

The energy consumption of the decentralized plants also warrants investigation. While their smaller footprint suggests potential energy savings, it is essential to assess the actual energy requirements of individual process units and equipment to determine the overall energy efficiency. Comparisons with the energy consumption of centralized pumping stations can provide valuable insights into the most sustainable and cost-effective option.

Furthermore, both options have implications regarding area availability. While the centralized option requires more space, finding one suitable location may be easier than identifying four separate locations for decentralized plants. The availability of suitable land, local constraints, and environmental considerations should all be considered during the decision-making process.

In conclusion, a thorough analysis is necessary to weigh the pros and cons of the centralized treatment plant with a wetland against the option of four decentralized plants. Factors such as treatment efficiency, space requirements, operational costs, total investment costs, energy consumption, and area availability must all be carefully considered. Only through a comprehensive evaluation can the optimal solution be determined, ensuring an efficient and sustainable treatment approach that meets the specific needs of the given context.

6. Conclusion and recommendations

Based on the comparison of collection system options, the consultants recommend the Low Pressure Sewer System with grinder pump, the key determining factors of this recommendation are:

A STEP system is not feasible for OWT as the advantages of such a system would not be realized due to all the issues with the existing septic tanks.

If it is considered, the implementation of a gravity sewer network with pumping stations would need to have more lift stations serving clusters of households to minimize the installation cost. A subsequent phase of investigation (i.e. pre-design) should find the balance between a full-fledged gravity sewer network with the necessary lift stations or a mix with more lift stations serving cluster of homes.

A clearer picture and extent of a collection system with optimal placing of Lift Stations (a basic topographical study will be needed which could be expanded upon for detailed design purposes should it proceed to that).

According to the consultant's comparison of wastewater treatment options based on the limited information currently available to us, the Treatment Wetland (TW) French System, seems the most suitable solution for treatment as:

- It complies with the effluent standards,
- It is possible to be installed in the given area,
- It is the simplest treatment option regarding O&M,
- It has the lowest energy and sludge handling costs,
- It has the lowest equipment costs.

However, the most feasible treatment process and the number of plants to be provided must consider all aspects including a phased approach which could be a major consideration, as well as pumping over large distances to move wastewater from the downstream edge of one drainage basin to another with the subsequent larger Lift Stations, Force Mains, and much larger gravity sewers to handle the pumped inflows. Consider the risks of pipe failures as well, power outages and other issues which centralized systems bring into play. The OWC should be aware of the phasing and cost implications for the public and other operational and maintenance issues.

Clearly, a thorough analysis is necessary, to build upon and enhance this preliminary viability study, to assess the pros and cons of a centralized treatment plant with one wetland versus the option of four decentralized plants.

The technical and economic viability of a proposal is defined by specific parameters as described above. The 'political' viability is more closely associated with the information understood by the broader community and the opinions or beliefs that are widely held within that community. Ideally, community members themselves should be aware of wastewater issues and prioritizing them, while advocating for a WWTF or other appropriate solution. The consultants – albeit limited – interaction with members of the community, the Council and the DoE suggests that a strategy should be developed and implemented even while the technical and economic approaches are finalized. Such a strategy might include:

a. Collection of data regarding point polluters, especially with regards to the New River.
b. Information sharing with the Orange Walk Town community (beyond the Town Hall meetings which have already been held with limited effect) – with an emphasis on the economic and environmental importance of a healthy New River.
c. Demonstration of both official interest and official capacity for action by addressing point pollution (now would be perhaps the best time to implement such action, immediately in advance of the rainy season when the health of the river can be expected to naturally improve), This might include enforcing the existing effluent

licenses (apparently expired) and enforcing the appropriate empowering legislation with worst offenders, while offering those same offenders access to inexpensive funding to resolve their issues through the BWRF.

d. Inviting BWSL to develop business model options for consideration by the community (including possible tariffs) and by DoE, the BWSL Board and the Town Council.
e. Implementation of the proposed public awareness campaigns including community involvement and education activities such as plantings along the banks of the New River to replace the Riparian forest.

6.1 Rough estimation of the CAPEX

Based on approximate figures, it can be estimated that the specific costs for the sewer system will range from USD 200 – 300 per meter. As for the wastewater treatment plant, the specific cost range is estimated to be between 150 – 200 USD per person equivalent (pe). This results in total costs for Orange Walk town in the range of 35 – 44 million USD, considering a complete sewer network spanning 124,000 kilometers and a projected population of 23,396 inhabitants by 2042.

It should be noted that costs from the Belize Water Services Limited (BWSL) may exceed the indicated values, as a precise cost basis for Belize is not available.

Based on this estimation, it is highly recommended to assess the feasibility of implementing the project in incremental stages. Both proposed solutions allow for step-by-step expansion of the plant size. However, it is important to understand that the plant costs account for only about 15-20% of the total system costs. Therefore, it is crucial to explore options that prioritize areas with higher population density.

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Annexes

6.1.1 Annex 1: Population and volume of wastewater projection – Orange Walk Town

Table 8:
Growth rate

Year	Population	Households	Growth rate (%)	
1980	8,439			
1991	11,014		1980 - 1991	2.45%
2000	13,572	3,066	1991 - 2000	2.35%
2010	13,709	3,375	2000 - 2010	0.10%
			Average	1.63%

Source: Census data, SIB

Table 9:
Population projection

Year	Population	Growth rate (%)
2010	13,709	1.63%
2020	16,120	1.63%
2023	16,922	1.63%
2024	17,199	1.63%
2025	17,480	1.63%
2026	17,765	1.63%
2027	18,055	1.63%
2028	18,350	1.63%
2029	18,649	1.63%
2030	18,954	1.63%
2031	19,263	1.63%
2032	19,578	1.63%
2033	19,898	1.63%

Year	Population	Growth rate (%)
2033	19,898	1.63%
2034	20,223	1.63%
2035	20,553	1.63%
2036	20,888	1.63%
2037	21,229	1.63%
2038	21,576	1.63%
2039	21,928	1.63%
2040	22,286	1.63%
2041	22,650	1.63%
2042	23,020	1.63%
2043	23,396	1.63%

Table 10:
Volume wastewater projection

Year	Population	Volume (GPD)
2010	13,709	362,193
2023	16,922	447,081
2024	17,199	454,399
2025	17,480	461,823
2026	17,765	469,353
2027	18,055	477,015
2028	18,350	484,808
2029	18,649	492,708
2030	18,954	500,766
2031	19,263	508,930
2032	19,578	517,252
2033	19,898	525,707
2034	20,223	534,293
2035	20,553	543,012
2036	20,888	551,863
2037	21,229	560,872
2038	21,576	570,040
2039	21,928	579,339
2040	22,286	588,798
2041	22,650	598,415
2042	23,020	608,190
2043	23,396	618,124

6.1.2 Annex 2: Comparison of wastewater collection system options

Category	Low Pressure Sewer	Gravity sewer & pumping system
Feasibility in prevailing topographic conditions		
Drainage	Feasible	Feasible
Capital Expenditure	Low to medium	High to medium
Operating expenditure		
Electricity	Low demand	High demand
Number of operators	Two operators required for preventative maintenance	Two operators required for preventative maintenance
Sludge removal (septic tanks)	Required	Not required
Complexity of the system	Pretreatment unit to be installed or used existing pretreatment unit	A minimum velocity must be maintained to prevent the depositing of solid in the sewer
Availability of spare parts and service providers	Available in country	Available in country
Level of training (operators)	Low level of training required for O&M	Medium level of training is required for O&M Staff.
Interaction of customer		
Customer training requirement	Some training or education required for homeowner.	Not required
Private property access	Access to septic tanks required	No access necessary

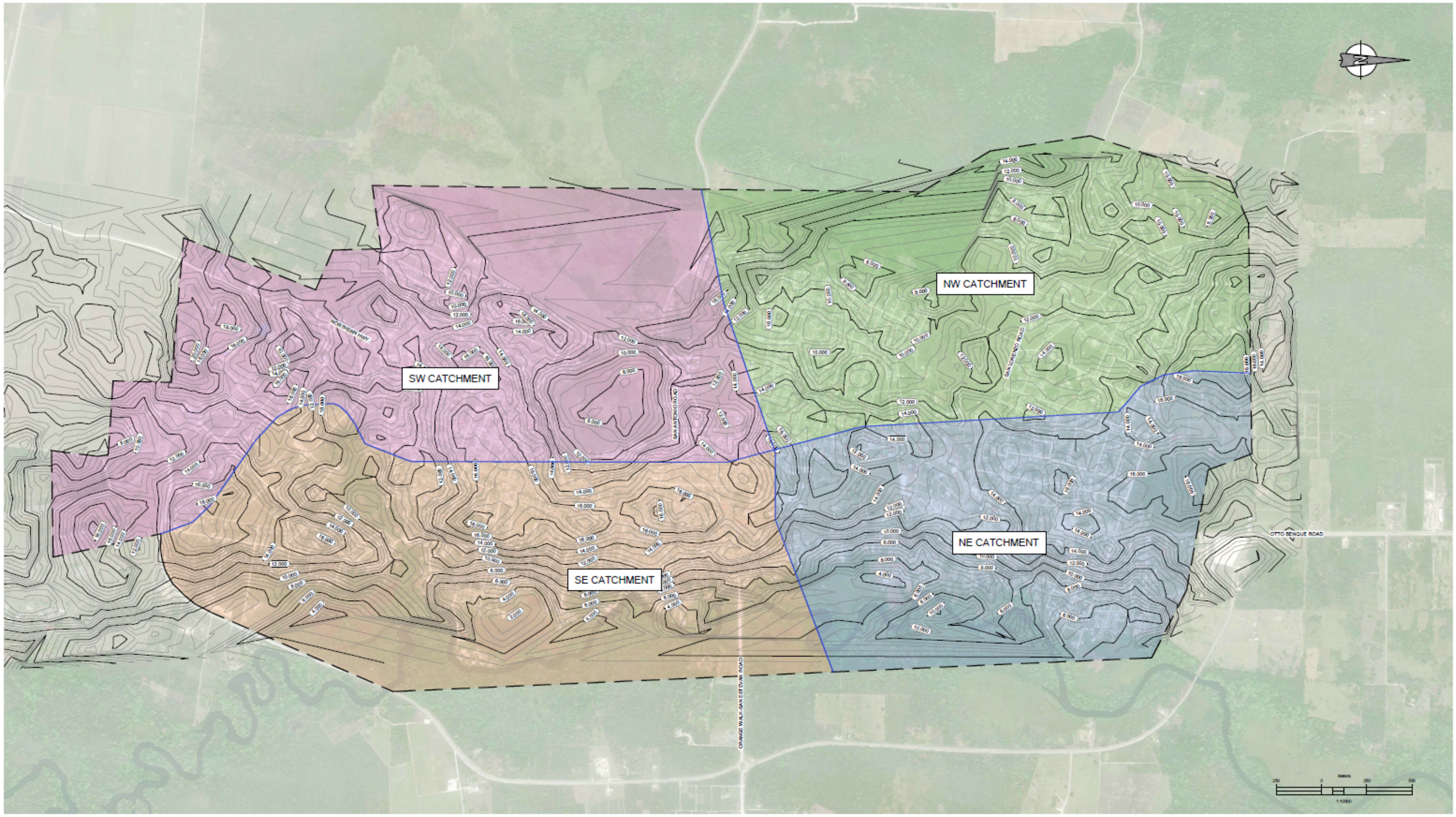
6.1.3 Annex 3: Comparison of wastewater treatment options

Category	Biological aerated filters	Treatment wetland - French System
Land requirement		0.8 m²/p.e
Flexibility to hydraulic and organic load	Flexible systems for shock loading due to the batch operation.	With high retention times, flow and load peaks are well tolerated
Vector and Odor Problem	No significant issues	Limited potential for problems
Capital expenditure	Moderate	Moderate
Operating expenditure	Relatively high	Low cost
Electricity	High power requirement	Very low power requirements
Number of operators	One operator required	Part-time operator required (25%)
Maintenance	Relatively high	Low
Complexity of the system		
Spare parts and service providers	Availability only outside of region (USA)	Full availability in country
Skill level required to Operate	Moderate skill level for day-to-day operation but qualified supervision needed in order to react to changes.	Operational simplicity. Minimal skills required.
Primary Treatment	No primary treatment needed	For this type of wetland, no
Sludge generation	Sludge dewatering needed; sludge is stabilized.	No separate sludge treatment needed; sludge treated in the French System
Tertiary treatment	Suitable for UV disinfection	Retention of helminth eggs, suitable for UV disinfection
Automatization	Easy to automatize for control purposes and automatization is a pre-condition for the process.	Almost no need for automatization besides flow metering and switching of beds

6.1.4 Annex 4: Layout for project extension

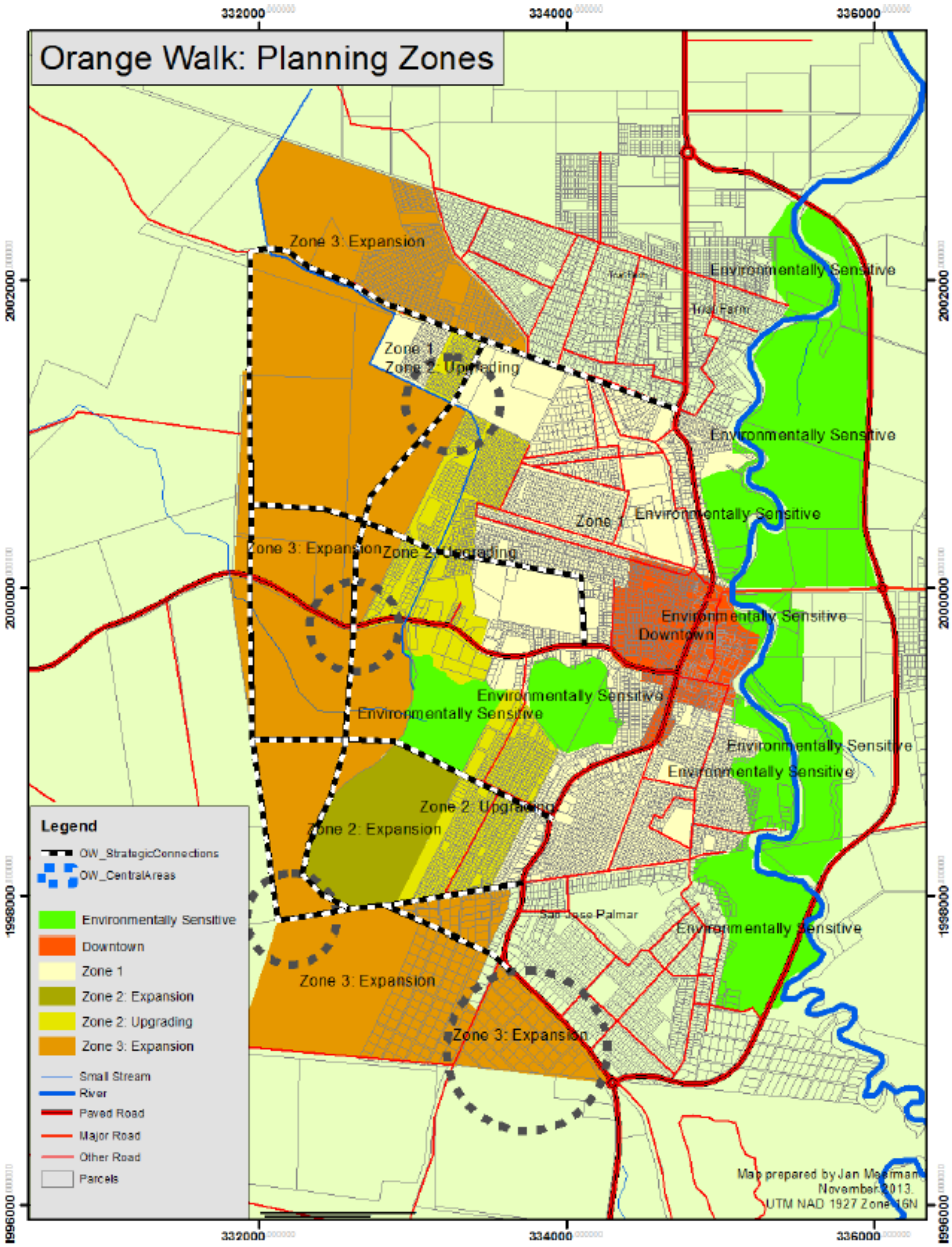
Source: ©GIZ / AKUT

6.1.5 Annex 5: Layout for contours and catchment areas



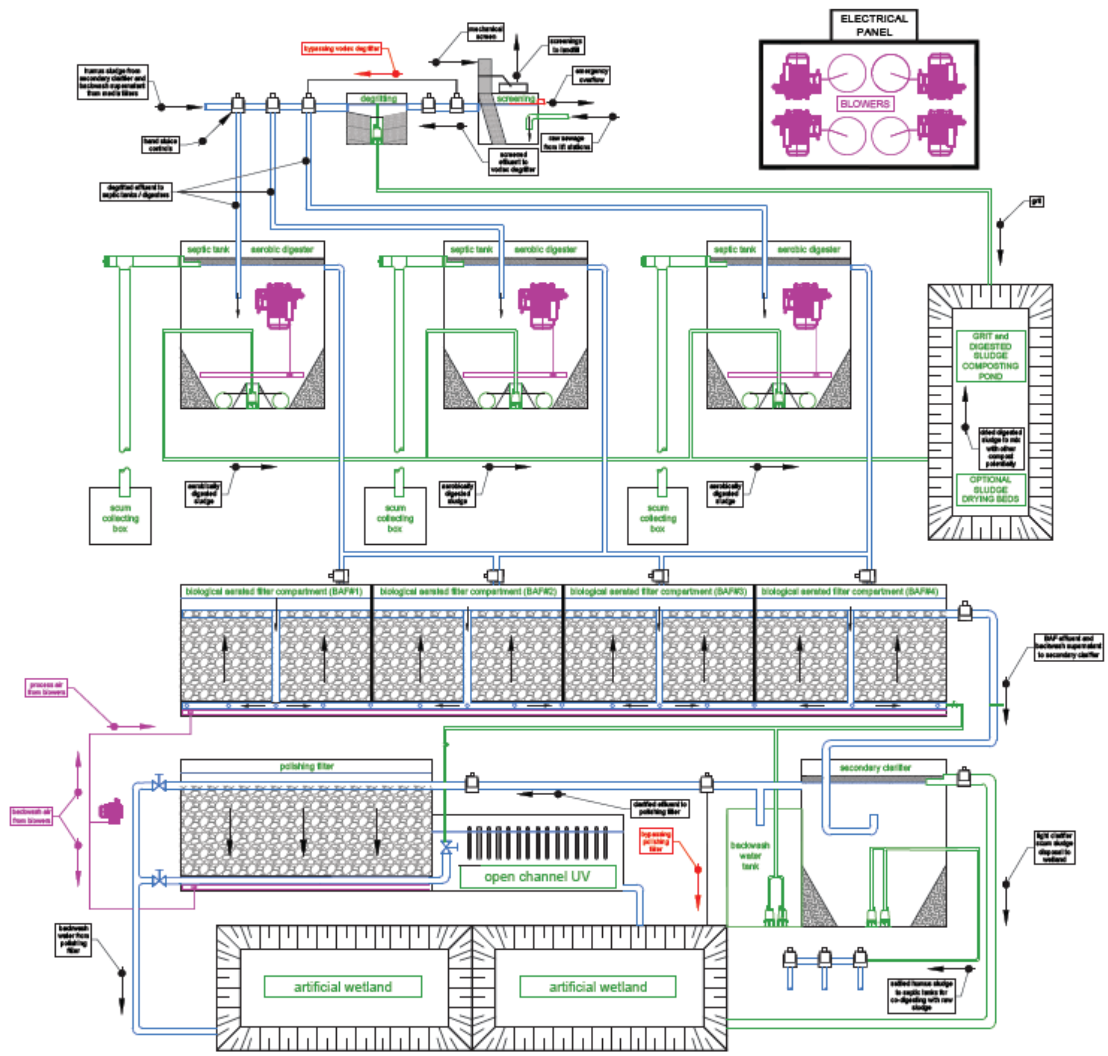
Source: ©GIZ / AKUT

6.1.6 Annex 6: Layout for planning zones



Source: Orange Walk Town Municipal Profile

6.1.7 Annex 7: BAF process and flow diagram



Source: JDB Project Engineering

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