# ECOLOGICAL WATER QUALITY ASSESSMENT OF THE SOUTH STANN CREEK RIVER AT MILE 21 ½ SOUTHERN HIGHWAY

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Education Empowers a Nation

Department of Science
Faculty of Science and Technology
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## ABSTRACT

Increased deforestation and the use of fertilizers and pesticides in banana plantations may cause physical and biological impacts to aquatic environments. This project aims to assess the ecological status of a portion of the South Stann Creek River, a watercourse in southeastern Belize, which passes along banana plantations and citrus orchards, eventually meeting the Caribbean Sea. Two sites were selected in the vicinity of a banana plantation at 21 ½ miles Southern Highway for this study. Sampling and testing for water quality, and a stream visual assessment protocol (SVAP) was used to assess the health of the river during a wet period (rainfall) and a dry period (no rainfall).Additionally, the water flow at both sites was determined and macroinvertebrate specimens were collected, preserved, and identified down to the family taxonomic level. Results indicate the presence of a total of 182 aquatic specimens, distributed into 10 different families, and 1 family common to both sites. The Families: Chironomidae, Thiaridae, Decapoda, Gerridae, Psephenidae, and Leptoceridae were found in Site #1, with the Family:Thiaridae being the most abundant. In Site #2, the Families Baetidae, Tricorythidae, Leptophlebiidae, Hydrachnidiae, Libellulidae, and Gerridae were found, with the Families:Baetidae and Leptophlebiidae being the most abundant. The health of the selected sites using the SVAP had an overall score ranging from 5.9 to 6.6, scoring the health of the river segment as poor or fair. The pH from the water quality test ranged from slightly acidic during the wet period to neutral/slightly basic during the dry period. Temperatures, water flow, and dissolved oxygen (DO) saturation also varied depending on the time the samples were collected. Assessment of the river is important for both aquatic and land organisms as well as for individuals that utilize the river.

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**TABLE OF CONTENTS**

## LITERATURE REVIEW

Banana plantations require the complete transformation of lowland environments. This includes the draining of marshes to allow for the cultivation of the fruit and the construction of the plantation. Streams are channelized and drainage canals are constructed to prevent flooding of the fields. The result of the increased deforestation directly and indirectly caused by the banana industry has impacted the physical and biological environments. About 75 percent of all diversity is held within the tropical forests (Panayotou & Ashton, 1992). The destruction of the rainforest habitat results in a loss of some of this plant and animal diversity. The removal of all vegetation exposes the soil to the intense and frequent rainstorms characteristic of the tropical lowlands. The high amount of rainfall percolating through the soil quickly leaches out nutrients. Water that is not absorbed by the soil becomes runoff and erodes the soil. As the soil becomes compacted by the intensive cropping, machinery, trampling of soil, removal of organic material, and pounding of rain; the soil's ability to absorb water decreases and runoff and erosion increases. The removal of vegetation along streams destabilizes their banks and increases lateral erosion. The result is the rapid erosion of the once fertile floodplains and increased sedimentation in streams and water bodies. (McCracken, 1998).

In addition to nutrients leaching out, pesticides as well as other forms of agrochemicals used in banana plantations may make its way into surrounding water bodies. These nutrients and pesticides may enter watercourses and pose ecological risks to aquatic ecosystems (Castillo, et al., 2006). At least 25% of the pesticides that are sprayed on banana crops from aircrafts never reach their target, but instead land on ponds, streams, or farmland (vanArsdale, 1991). The watercourses eventually lead out into the sea whereby it can affect marine aquatic ecosystems+. According to the Peninsula Citizens for Sustainable Development in Belize, in tropical and subtropical areas like Belize, banana plantations and citrus groves are major sources of pesticide laden agricultural run-off. Bananas plantations, in particular, are a major source of insecticides and other pesticides because of bananas' extreme vulnerability to insects. Large amounts of plant and animal life are lost from the intensive use of chemical agents. Nematicides used to kill parasitic worms are highly toxic for distinct types of fauna (fish, birds, reptiles, bees, livestock, etc.) and high death rates of fish have been detected after spraying and after heavy rains (Kopetski, Kim, Cave, & Milner, 2002).

Fertilizer runoff from farms can trigger sudden explosions of marine algae capable of disrupting ocean ecosystems and producing oxygen "dead zones" in the sea (Peninsula Citizens for Sustainable Development, 2012). This results in marine plants and animals unable to breathe, eventually leading to death. Pesticides in runoff can also pose health problems in humans and marine lives. Plus, many of the chemicals used in pesticides can change the reproductive cycles of animals, birds and fish, causing them to be sterile, which results in harm to an entire eco-system.

Aquatic macroinvertebrates are considered important bio-indicators for monitoring environmental water quality (Stoian *et al*., 2009). Freshwater macroinvertebrate communities respond rapidly to an impact in the river (positive and negative), and are therefore able to reflect the present condition of a river in terms of the water quality and flow regime (Stoian *et al*., 2009; Thirion, 2007). Certain macroinvertebrates are more tolerant to pollution, while others are rather very sensitive to pollution. The presence of those that are sensitive to pollution or lack thereof allows us to better understand the level of pollution. River ecosystems provide essential goods and services, which are needed, directly or indirectly, for the survival and well-being of humanity (Rossouw, 2009). In order for rivers to keep providing these goods and services it is important to protect and manage these ecosystems (Ferreira I. , 2014). According to the Effluent Limitations (Amendment) Regulations (2009), the limitation standards of certain parameters are as follow: Temperature (33$^{o}$C), pH (6-9 units), and dissolved oxygen (DO 5 mg/L).

## INTRODUCTION

The South Stann Creek River is a watercourse in southeastern Belize. It rises in the foothills of the eastern slopes of the Maya Mountains within the Cockscomb Basin Wildlife Sanctuary; it drains the Cockscomb West Basin, and eventually leads out into the Caribbean Sea. Along its course, it passes through many citrus orchards and banana plantations. The extensive use of fertilizers and pesticides used in citrus orchards and banana plantations found along the South Stann Creek River pose a threat to marine ecosystems because the excess fertilizers and pesticides may drain into water ways and eventually find their way into the Caribbean Sea.

Apart from the banana plantation, a housing area where plantation workers reside is commonly found in banana farms in Belize as well. Farm workers living in the farm housing area use the South Stann Creek River for many activities such as swimming, washing clothing, and for fishing. Unfortunately, some of these activities also result in pollution to the water body. For example, it is common to observe people using detergents to wash clothing and shoes. Empty plastic bottles and used diapers are also observed along the banks of the river.

Macroinvertebrates have long been used as indicators to assess water quality. Certain macro invertebrates are tolerant to pollution while others may not be as tolerant. According to the US EPA (2012), aquatic macroinvertebrates are good indicators of stream quality because they are affected by the physical, chemical, and biological conditions of the stream, and cannot escape pollution therefore will show the effects of short- and long term pollution events. They may show the cumulative impacts of pollution and impacts from habitat loss not detected by traditional water quality assessment. They are a critical part of the stream’s food web.

In the present project, an ecological assessment was done on the South Stann Creek River. The objective of the study was to determine the overall health of a section of the river, near a banana farm.

## MATERIALS AND METHODS

*Site Description*

The site selected for this study is a section of the South Stann Creek river near a banana farm located at 21 ½ miles Southern Highway in the Stann Creek District, Belize C.A. The farm has been around for more than 30 years, with 4 banana plantations, some being older than others. Together the farm has 1,345 acres of land under banana production. Each of the 4 four plantations possesses a packaging plant whereby the bananas are cut from the stalk, sprayed, sorted, washed, and packaged for shipping. In addition, the farm has a housing area in which farm workers live. The farm is one amongst many in the world that produces and packages bananas under the Fyffes brand of foods. Fyffes plc is a leading importer and distributor of tropical produce, headquartered in Dublin, Ireland.

The South Stann Creek River runs along a banana plantation. From the plantation, the river is approximately 9 – 10 miles from the Caribbean Sea. The river does not only pass through the banana plantation but also other citrus farms along the way. Along the river, two sites with the coordinates N 16º42.918’ W 088º24.874’ and N 16º43.074’ W 088º25.215’ were selected for the study. Site #1 (N 16º42.918’ W 088º24.874’) was located near a housing area adjacent to the river and the banana plantation. Site #2 (N 16º43.074’ W 088º25.215’) was located near the water pump of the plantation where water is extracted from the river for irrigation purposes for the plantation.

*Macroinvertebrates Sampling*

Macroinvertebrates were collected using two methodologies. First, line transects each of 10 meters were set and macroinvertebrates were collected along the path while the sediment was disturbed. This method yielded a small number of organisms; therefore, a timed approach was used in which a 10 square meter area was sampled over a 30 min period. In this method, the sediments were disturbed using physical methods of wading within the waters. Following closely behind, a D-frame aquatic net was held facing against the stream flow to capture any macroinvertebrates emerging from the disturbed sediment floor. Samples collected were poured into a series of mesh hand screens of various sizes (5, 10, 60, and 120µm). The samples were washed and the specimens were collected, preserved in 70% ethanol, and were later identified down to the family taxonomic level.

Fish were not part of this assessment as they were not observed in the waters due to the high turbidity level of the water.

*Visual Stream Assessment Protocol (VSAP)*

An assessment of the general health of the section of the river in the study site was performed. For this assessment, a Rapid Ecological Assessment (REA) was used, utilizing the Visual Stream Assessment Protocol (VSAP)(USDA, 1998). The assessment was conducted on April 1st, 2015.A VSAP assigns scores to features in a stream system that affects its overall condition. Features that were evaluated included channelization, hydrologic alteration, the riparian zone, stability of the bank, water appearance, nutrient enrichment, barriers to fish movement, in-stream fish cover, pools, and insect/invertebrate habitats. The features were given a score ranging from 1 – 10, with 1 being poor health and 10 being excellent stream health. An overall score was tabulated to determine the general health of the river.

*River Flow Rate*

The flow rate of the river was estimated using the float method. A measuring tape was used to mark a length of 25m along a straight portion of the river. The water flow of the stream was then estimated by using oranges and a stop watch. An orange was released at one end of the line. The time it took for the orange to reach the other end of the line was recorded. This process was repeated twice with another orange of approximately the same size. The width of the river at each end and at the middle of the 25 m line was measured. Along the widths, the depth of the river was measured in three instances; at both edges of the river and the middle. The flow rate of the section of the stream which is the result of the velocity of water flowing (V = [final distance x(f) – initial distance x(i)] ÷ average time (t)) down the stream multiplied by the cross sectional area (width x average depth) of the stream bed was calculated.

*Water Quality Testing*

In situ physical and chemical water quality parameters were measured using a YSI 556 MPS (multi probe system). Parameters measured include temperature, dissolved oxygen (DO), salinity, pH, and conductivity. Measurements were taken in triplicates: at the top, middle, and bottom layer of the water. At each site sampled, measurements were taken across a transect of the river; at both edges of the river and at the middle.

## RESULTS AND DISCUSSION

General characteristics of the study site are presented in Table 1. The mean widths of the river at the two sampling sites were similar; while the mean depth of the river at the sampling site varied.

**Table 1. General Characteristics of the South Stann Creek River at two Sites located at mile 21 ½ Southern Highway.**

| **Sampling Time** | **Site #** | **Coordinates** | **Mean Width (m)** | **Mean Depth (m)** |
|---|---|---|---|---|
| **After heavy rainfall** | 1 | N 16$^{o}$42.918' W 088$^{o}$24.874' | 25 | 86.83 |
| | 2 | N 16$^{o}$43.074' W 088$^{o}$25.215' | 24.8 | 93.33 |
| **No rainfall** | 1 | N 16$^{o}$42.918' W 088$^{o}$24.874' | 23.8 | 40.34 |
| | 2 | N 16$^{o}$43.074' W 088$^{o}$25.215' | 25.8 | 92 |

*Macroinvertebrate Collection*

Approximately 182 macroinvertebrates were collected, distributed into 10 different families, and 1 family common to both sites. Photographs of the macroinvertebrates were to help aid in identification and classification. The families Chironomidae, Thiaridae (Gastropoda), Decapoda (freshwater shrimp), Gerridae, Psephenidae, and Leptoceridae were found in Site #1, with the family Thiaridae (Gastropoda) being the most abundant. Thiaridae cannot tolerate pollution as they require oxygen rich water. In Site #2, the families Baetidae, Tricorythidae, Leptophlebiidae, Hydrachnidiae (Hydracarina), Libellulidae, and Gerridae were found, with the families Baetidae and Leptophlebiidae being the most abundant. Baetidae and Leptophlebiidae are both families of mayflies with about 900 described species distributed worldwide. Mayflies breed in a wide range of waters from lakes and streams to ditches and even water butts. The nymphs are strong swimmers and feed mainly on algae. Mayflies are abundant and diverse aquatic insects in both lentic and lotic environments, especially in streams (Brittain, 1982).They are good bioindicators due to their low tolerance to environmental change (da-Silva & Domingues, 2009). May flies are typical in high sediment water environments often indicators of low pH and high sediment water environments (Ferreira, 2014). They prefer cleaner water therefore their presence indicates clean water sources.

*Water Quality Results of Sites during Wet and Dry Period*

Results of water quality parameters are presented in Tables 2-5. During the first visit, not all readings were obtained from the river as shown in Table 3. During the second visit, there had been no rainfall for several days prior to the visit. The water levels had decreased and were relatively low. Hence, a measurement was not possible from the middle of the river due to how low it was; only one reading was possible as shown in Table 4.

**Table 2. Physical and Chemical Variables of Site #1(After Heavy Rainfall).**

| River Area | Rep # | Temperature (ºC) | Conductivity (μs/cm$^3$) | Salinity (ppt) | DO (%) | DO (mg/L) | pH |
|---|---|---|---|---|---|---|---|
| **Sand Pit Edge of River** | 1 | 23.83 | 0.045 | 0.02 | 16.5 | 1.35 | 5.02 |
| | 2 | 23.81 | 0.045 | 0.02 | 22.6 | 1.91 | 5.12 |
| | 3 | 23.81 | 0.045 | 0.02 | 24.1 | 2.03 | 5.17 |
| **Middle of River** | 1 | 23.75 | 0.045 | 0.02 | 14 | 1.18 | 4.9 |
| | 2 | 23.8 | 0.045 | 0.02 | 17.6 | 1.48 | 5.14 |
| | 3 | 23.8 | 0.045 | 0.02 | 17.3 | 1.46 | 5.25 |
| **Vegetation Edge of River** | 1 | 23.8 | 0.045 | 0.02 | 14.2 | 1.2 | 5.08 |
| | 2 | 23.79 | 0.045 | 0.02 | 20.4 | 1.72 | 5.32 |
| | 3 | 23.79 | 0.045 | 0.02 | 19.9 | 1.68 | 5.43 |

**Table 3. Physical and Chemical Variables of Site #2(After Heavy Rainfall).**

| River Area | Rep # | Temperature (°C) | Conductivity (μs/cm$^3$) | Salinity (ppt) | DO (%) | DO (mg/L) | pH |
|---|---|---|---|---|---|---|---|
| Water Pump End of River | 1 | 23.85 | 0.044 | 0.02 | 10.1 | 0.84 | 8.09 |
| | 2 | 23.85 | 0.044 | 0.02 | 12.7 | 1.06 | 8.07 |
| | 3 | 23.84 | 0.044 | 0.02 | 12.7 | 1.07 | 7.91 |
| Middle of River | 1 | - | - | - | - | - | - |
| | 2 | - | - | - | - | - | - |
| | 3 | - | - | - | - | - | - |
| Vegetation Edge of River | 1 | - | - | - | - | - | - |
| | 2 | - | - | - | - | - | - |
| | 3 | - | - | - | - | - | - |

**Table 4. Physical and Chemical Variables of Site #1 (No Rainfall).**

| River Area | Rep # | Temperature (°C) | Conductivity (μs/cm$^3$) | Salinity (ppt) | DO (%) | DO (mg/L) | pH |
|---|---|---|---|---|---|---|---|
| Sand Pit Edge of River | 1 | 29.17 | 0.075 | 0.03 | 3.3 | 0.25 | 7.84 |
| | 2 | 29.19 | 0.075 | 0.03 | 3.8 | 0.30 | 7.8 |
| | 3 | 29.21 | 0.075 | 0.03 | 4.8 | 0.37 | 7.8 |
| Middle of River | 1 | 29.17 | 0.075 | 0.03 | 4.4 | 0.34 | 7.74 |
| | 2 | - | - | - | - | - | - |
| | 3 | - | - | - | - | - | - |
| Vegetation Edge of River | 1 | 29.16 | 0.076 | 0.03 | 4.5 | 0.34 | 7.72 |
| | 2 | 29.21 | 0.076 | 0.03 | 4.8 | 0.37 | 7.71 |
| | 3 | 29.21 | 0.076 | 0.03 | 4.9 | 0.38 | 7.71 |

**Table 5. Physical and Chemical Variables of Site #2 (No Rainfall).**

| River Area | Rep # | Temperature (ºC) | Conductivity (μs/cm$^3$) | Salinity (ppt) | DO (%) | DO (mg/L) | pH |
|---|---|---|---|---|---|---|---|
| **Water Pump End of River** | 1 | 29.08 | 0.063 | 0.03 | 6.1 | 0.47 | 7.76 |
| | 2 | 29.09 | 0.063 | 0.03 | 9.2 | 0.7 | 7.09 |
| | 3 | 29.12 | 0.063 | 0.03 | 9.7 | 0.74 | 7.08 |
| **Middle of River** | 1 | 29.09 | 0.063 | 0.03 | 6.7 | 0.51 | 7.07 |
| | 2 | 29.11 | 0.063 | 0.03 | 9.2 | 0.7 | 7.07 |
| | 3 | 29.11 | 0.063 | 0.03 | 9.1 | 0.7 | 7.08 |
| **Vegetation Edge of River** | 1 | 29.09 | 0.063 | 0.03 | 5.2 | 0.41 | 7.09 |
| | 2 | 29.1 | 0.063 | 0.03 | 6.4 | 0.49 | 7.05 |
| | 3 | 29.11 | 0.063 | 0.03 | 6.6 | 0.51 | 7.07 |

The temperatures after heavy rainfall were lower compared to the temperature during the dry weather sampling. This is expected because during the dry weather sampling the sun was more intense and the water level was lower permitting more heating of the water. DO was also different whereby the saturation was higher during rainfall sampling and lower during the dry weather. In both samplings the DO levels were low. This presents a problem for aquatic life living in the section of the river sampled. DO is necessary to many forms of life including fish, invertebrates, bacteria, and plants. They require oxygen for respiration. It enters the water through the air or as a plant byproduct. Oxygen from the air slowly diffuses across the water's surface or can be mixed in quickly through aeration caused by man, wind, rapids, waterfalls, etc (Kemker, 2013). Temperature also plays a role in the amount of oxygen that can be diffused. At lower temperatures, more oxygen is diffused into the water. At higher temperatures, DO saturation will be less. This relationship between DO and temperature is evident in the YSI readings obtained. During rainfall, the water temperatures were lower (colder) and the DO saturation was higher, with values ranging from 0.84 mg/L in Site #2 to 2.03 mg/L in Site#1. During the dry weather (no rainfall), the water temperatures were higher (warmer) and the DO saturation was lower, with values ranging from 0.25 mg/L in Site #1 to 0.74 mg/L in Site #2. Conductivity was seen to be higher during the dry weather than the rainy weather with values being 0.045 and 0.044 μs/cm$^3$ in Sites 1 and 2 respectively during the rainy weather (rainfall), and 0.075 and 0.063 in Site 1 and 2 respectively during the dry weather (no rainfall). The pH of the water ranged from 4.9 to 8, and the salinity ranged from 0.2 to 0.3 ppt. With the exception of the pH below 6 observed only in one sampling site during the rainfall sampling, both parameters were within acceptable EPA and Belize Department of the Environment ranges for fresh water (Effluent Limitation Amendment Regulations 2009).

*Stream Visual Assessment Protocol Scoring of Site #1 & #2*

A Stream Visual Assessment Protocol (SVAP) was done at both sites on both visits (**Appendix A)**. This assessment protocol provides a basic level of steam health evaluation, and provides an assessment based primarily on physical conditions within the assessment area (USDA, 1998).

Table 6 shows the SVAP scores of Site #1 for both visits. In Site #1, there was evidence of channelization whereby the channel was altered and recovered. Along the stream channel, down cutting was observed indicating channelization or straightening of the stream. Piles of sand on the sides of the bank were evidence of this as well, in which one side of the river did not possess any vegetation for two channel widths. The riparian zone was evident on at least one side of the river which extends one channel width. Vegetation such as tall grass, trees, and yellow bamboo were found along one side of the bank, stabilizing the bank. The banks were somewhat low; however, the vegetation kept the land from eroding any further. Based on these conditions observed, the stability of the bank was therefore given a score of 7. The water appeared to have a brownish color. This was most likely due to the heavy rainfall and the mixing of sediments due to increased stream flow. However, during the dry period of no rainfall, the water appeared clear and the bottom was visible. Compared to the first visit, the water level was much lower during the second visit. The overall score of Site #1 were 5.9 and 6.1 for the first and second visit respectively. A score of 5.9 shows that the health of the river at the site was poor and a score of 6.1 shows that the health was fair during the second visit (Table 7).

Table 6 also shows the SVAP scores of Site #2 for both visits. Similar to the first site, there was evidence of recovery of the channel with rocks being placed on the edge of the river near the plantation where the water pump was stationed. The bank on one end was considerably high and a portion was eroded due to the incoming waters from the river. Fallen tree shrubs in the middle of the river provided a strong current which pushes water against the bank. However, bamboo vegetation protected the surface area of the bank from being further eroded. Therefore, the bank stability was scored 7. The water during the first visit was brown due to increased rainfall and stream flow continuously stirring up sediments, and during the second visit, the stream flow was slower and the water appeared clearer. The river bottom was visible to some extent due to deep pools in the river. There were several trees that had fallen into the waters and proved to be a barrier to fish movement. These same trees also serve as fish cover and as invertebrate habitat, as well as the deep pools, the boulders and rocks set on the river edge, and overhanging bamboo vegetation that dip into the waters when the water levels are high enough. The overall scores of the river at Site #2 were 6.3 and 6.6 for the first and second visit respectively. Both scores indicate that the river's health condition was fair as determined using the SVAP scoring matrix (Table 7).

**Table 6. SVAP Score of Sites**

| **PARAMETER** | **Site #1** | | **Site #2** | |
|---|---|---|---|---|
| | **Rainfall** | **No Rainfall** | **Rainfall** | **No Rainfall** |
| Channel Condition: | 3 | 3 | 3 | 3 |
| Riparian Zone: | 8 | 8 | 8 | 8 |
| Water Appearance: | 5 | 9 | 5 | 8 |
| Barriers to Fish Movement: | 10 | 8 | 5 | 4 |
| Pools: | 3 | 3 | 7 | 7 |
| Hydrologic Alteration: | 7 | 7 | 6 | 6 |
| Bank Stability: | 7 | 7 | 7 | 7 |
| Nutrient Enrichment: | 10 | 10 | 10 | 10 |
| In-stream Fish Cover: | 3 | 3 | 5 | 5 |
| Invertebrate Habitat: | 3 | 3 | 7 | 8 |
| **Overall Score:** | **5.9** | **6.1** | **6.3** | **6.6** |

**Table 7. SVAP Scoring and Status**

| **Score** | **Status** |
|---|---|
| < 6.0 | Poor |
| 6.1 – 7.4 | Fair |
| 7.5 – 8.9 | Good |
| >9.0 | Excellent |

*Flow Rate*

The flow rate of the section of the river which is the result of the velocity of water flowing (V = [final distance x(f) - initial distance x(i)] ÷ average time (t)) down the stream multiplied by the cross sectional area (width x average depth) of the stream bed was calculated. The readings obtained of the time it took the oranges to float down the transect chosen is presented in Table 8.

**Table 8.Water Flow Time**

| **Rep** | **Time (s)** | | | |
|---|---|---|---|---|
| | **Visit #1 (Rainfall)** | | **Visit #2 (No Rainfall)** | |
| | **Site #1** | **Site #2** | **Site #1** | **Site #2** |
| 1 | 31.34 | - | 62 | 27.64 |
| 2 | 30.31 | - | 79.9 | 24.41 |
| 3 | 31.72 | - | 78.7 | 30.55 |
| 4 | 27.66 | - | 70.1 | 28.14 |
| **Average (t)** | **30.28** | **-** | **72.68** | **27.69** |

The cross-sectional area (A) of the river section was calculated using the equation: A ($m^2$) = avg depth (D) X avg width (W).

Velocity of Water Flowing: V (m/s) = ([x(f) – x(i)] / (t))

Flow Rate: F= V * A

**Rainfall:**

Site #1: F = (25m/30.28s) * (25m*0.8683m)

= **17.92 $m^3$/s**

Site #2: Not available for calculation due to rapid and haphazard water flow.

**No Rainfall:**

Site #1: F = (25m/72.68s) * (23.8m*0.40335m)

= **3.302 $m^3$/s**

Site #2: F = (25m/27.69s) * (25.8m*0.92m)

= **21.43 $m^3$/s**

When comparing the flow rate of the river during the raining and the dry sampling times, a higher flow rate was observed during the raining sampling. This was expected because during the rainfall period, the water flow was fast due to the increase in waters coming from the mountainous areas of the Cockscomb Basin Wildlife Sanctuary that enters into the river. During the dry period of no rainfall, the water levels were lower than the previous visit. The water flow was therefore slower than previous visit in Site #1. As for Site #2, the flow rate was not able to be calculated due to the dangerous river flow that inhibited the depth and width of the river site to be determined. However, during the second visit, the waters was much calmer and was passable, therefore a flow rate was able to be calculated. The flow rate at Site #2 was considerably faster than Site #1 due to the higher water levels.

## CONCLUSION

The assessment carried out indicates that the overall health of the river at the location studied is fair. Human activities observed such as clearing of riparian buffer and use the river for washing may be contributing to such condition. The low pH observed at one site may also be attributed to human activities as could possibly be due to the effluents from the many citrus and banana plantations that influence the South Stann Creek River. However, further studies are required to be able better understand the status of the South Stann Creek River and to determine possible causes and sources of pollution to the river. It is important to note that during this study we were privy to water quality monitoring data carried out by banana farms near the study site. This is an indication of the willingness of these farms to monitor and reduce potential sources of pollution that may affect the river.

## REFERENCES

Allan, J., Erickson, D., & Fay, J. (1997). The influence of catchment land use on stream integrity across multiple spatial scales. *Freshwater Biology , 37*, pp. 149-161.

Brittain, J. (1982). Biology of mayflies. *Annual Review of Entomology* (27), 119-147.

Castillo, L., Martinez, E., Ruepert, C., Savage, C., Gilek, M., Pinnock, M., et al. (2006). Water quality and macroinvertebrate community respone following pesticide applications in a banana plantation, Limon, Costa Rica. *Sci Total Environ. , 367* (1), 418-32.

da-Silva, E., & Domingues, P. (2009). Bioindicadoes aquaticos continentais. *Saude & Ambiente em Revista , 4* (2), 87-93.

Effluent Limitations (Amendment) Regulations. (2009). Belmopan City.

Ferreira, I. (2014, January). Investigating the Influence of Hydrological Phase on Baetidae and Simuliidae Species Composition in a South African Non-Perennial River: The Seekoei River.

Ferreira, I. S. (2014). *INVESTIGATING THE INFLUENCE OF HYDROLOGICAL PHASE ON BAETIDAE AND SIMULIIDAE SPECIES COMPOSITION IN A SOUTH AFRICAN NON-PERENNIAL RIVER: THE SEEKOEI RIVER.* Doctoral dissertation, University of the Free State Bloemfontein.

Kemker, C. (2013, November 19). *Dissolved Oxygen.* Retrieved from Fundamentals of Environmental Measurements: http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/

Kopetski, E., Kim, R., Cave, A., & Milner, L. (2002, March 22). *The Ecological Footprint of Dole Banana.* Retrieved March 2015, from Banana Link: http://www.bananalink.org.uk/sites/bananalink.neontribe.co.uk/files/documents/Reports/ecological_footprint_kopetski_et_al.pdf

McCracken, C. (1998). *The Impacts of Banana Plantation Development in Central America.* Retrieved March 2015, from Tripod: http://members.tripod.com/foro_emaus/BanPlantsCA.htm

Panayotou, T., & Ashton, O. (1992). *Not By Timber Alone.* Washington D.C.: Island Press.

Peninsula Citizens for Sustainable Development. (2012). *Agricultural Threats to the Placencia Peninsula Environment.* Retrieved March 2015, from PCSD Belize:

http://www.pcsdbelize.org/agriculture_aquaculture/agriculture.html#Water-Borne_Pollution

Rossouw, N. (2009). *Dams and Environmental flows. Managing releases for livelihood security and ecosystem protection. Overview of the literature and practical lessons from the Berg River Dam.* Retrieved from Pepared for InWEnt, Capacity Building International Germany River Basin Dialogue Programme, Sustainable Major Water Infrastructure Development component. Implemented jointly with UNEP for the SADC Water Division & other regional development organisations: http://www.cdri.org.kh/shdmekong/11.BergDams%20and%20Environmental.pdf

Science Olympiad Student Center Wiki. (2015, February 24). *Water Quality/Macroorganism List*. Retrieved from Scioly: http://scioly.org/wiki/index.php/Water_Quality/Macroorganism_List

Stoian, L., Gagyi-Palffy, A., & Stan, G. (2009). Preliminary aspects regarding the use of some invertebrate bioindicator species in the ecological study of an auatic lotic ecosystem. *AACL Bioflux , 2*, 331-337.

Thirion, C. (2007). Module E: Macroinvertebrate Response Assessment Indec (MIRAI). In C. Kleynhans, M. Louw, C. Thirion, N. Rossouw, & K. Rowntree, *River EcoClassification: Manual for EcoStatus determination (Version 2).* Join Water Research Commision and Department of Water Affairs and Forestry Report. WRC Report No. KV 168/05. Water Research Commission, Pretoria.

US EPA. (2012, March 6). *Water: Monitoring & Assessment.* Retrieved April 2015, from EPA: http://water.epa.gov/type/rsl/monitoring/vms40.cfm

USDA. (1998, December). Stream Visual Assessment Protocol.

vanArsdale, C. (1991). Banana Development in Costa Rica. *Multinational Monitor , 12* (1 & 2).

**APPENDICES**

## Appendix A: STREAM VISUAL ASSESSMENT PROTOCOL (SVAP)

### Channel Condition

| | | | |
|---|---|---|---|
| Natural channel; no structures, drainage ditches. No evidence of down-cutting or excessive lateral cutting | Evidence of past channel alteration, but with significant recovery of channel and banks. Any drainage ditches are filling in and well vegetated. | Altered channel; <50% of the reach with riprap and/or channelization. Excess aggradations; braided channel. Drainage ditches inhibit flood plain functions. | Channel is actively down- cutting or widening. >50% of the reach with riprap or channelization. Multiple drainage ditches inhibit flood plain functions. |
| 10 | 7 | 3 | 1 |

### Hydrologic alteration

| | | | |
|---|---|---|---|
| Flooding every 1.5 to 2 years. No dams, no water withdrawals, no dikes or other structures limiting the stream's access to the flood plain. Channel is not incised. | Flooding occurs only once every 3 to 5 years; limited channel incision. or withdrawals, although present, do not affect available habitat for biota. | Flooding occur once every 6 to 10 years; channel deeply incised. Or withdrawals significantly affect available low flow habitat for biota. | No flooding occurs; channel deeply incised or structures prevent access to flood plain, or dam operations prevent flood flows. Or withdrawals have caused severe loss of low-flow habitat or Flooding occurs on a 1-year rain event or less. |
| 10 | 7 | 3 | 1 |

### Riparian Zone

| | | | |
|---|---|---|---|
| Natural vegetation extends at least two active channel width on each side or > 66 feet (THB) | Natural vegetation extends one and a half of an active channel width on each side. Or 66-31 feet (MB) | Natural vegetation extends a third of the active channel width on each side. Or 30-1 feet (TB) | Natural vegetation less than an active channel width on each side. Or lack of generation. Or <10 feet (NB) |
| 10 | 7 | 3 | 1 |

**Bank stability**

| | | | |
|---|---|---|---|
| Banks are stable; banks are low; > 33% of eroding surface outside bends protected by roots that extend to base flow elevation. | Moderately stable; banks are low; < 33% of eroding surface in outside bends is protected by roots that extend to base flow elevation. | Moderately stable; banks may be low, but typically are high; outside bends are actively eroding (some mature trees falling into stream annually, in some slopes failure apparent.) | Unstable; banks may be low, but typically are high; some straight reaches and inside edges of bends are actively eroding as well as outside bends (numerous mature trees falling into stream annually, numerous slope failures apparent.) |
| 10 | 7 | 3 | 1 |

**Water appearance**

| | | | |
|---|---|---|---|
| Very clear, or clear but tea-colored; objects visible at depth 3–6 ft (less if slightly colored); no oil sheen or foaming on surface; no noticeable film on submerged objects or rocks. | Occasionally cloudy, especially after storm event, but clears rapidly; objects visible at depth 1.5–3 ft; may have slightly green color; no oil sheen on water surface. | Considerable cloudiness most of the time; objects visible to depth 0.5–1.5 ft; slow sections may appear pea-green; bottom rocks or submerged objects covered with heavy green or olive-green film, or Moderate odor of ammonia or rotten eggs. | Very turbid or muddy appearance most of the time; objects visible to depth <1/2 ft; slow moving water may be bright-green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface, or Strong odor of chemicals, oil, sewage, other pollutants |
| 10 | 7 | 3 | 1 |

**Nutrient enrichment**

| | | | |
|---|---|---|---|
| Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present. | Fairly clear or slightly greenish water color along entire reach; moderate algal growth on stream substrates. | Greenish water color along entire reach; overabundance of lush green macrophytes; abundant algal growth, especially during warmer months. | Pea green, gray, brown water along entire reach; dense stands of macrophytes clog stream; severe algal blooms create thick algal mats in stream. |
| 10 | 7 | 3 | 1 |

**Barriers to fish movement**

| | | | | |
|---|---|---|---|---|
| No barriers | Seasonal water withdrawals inhibit movement within the reach. | Drop structures, culverts, dams, or diversions (<1 foot drop) within the reach. | Drop structures, culverts, dams, or diversions (>1 foot drop) within 3 miles of the reach. | Drop structures, culverts, dams, or diversions (>1 foot drop) within the reach. |
| **10** | **7** | **5** | **3** | **1** |

**In-stream fish cover**

| | | | | |
|---|---|---|---|---|
| >7 cover types available | 6 to 7 cover types available | 4 to 5 cover types available | 2 to 3 cover types available | None to 1 cover type available |
| **10** | **7** | **5** | **3** | **1** |

**Cover Types**: Logs/large woody debris; deep pools; overhanging vegetation; boulders/cobble; riffles; undercut banks; thick root mats; dense macrophyte beds; isolated/backwater pools; other ___________

**Pools**

| | | | |
|---|---|---|---|
| Deep and shallow pools abundant; greater than 30% of the pool bottom is obscure due to depth, or the pools are at least 5 feet deep. | Pools present but not abundant; between 10–30% of the pool bottom is obscure due to depth, or the pools are at least 3 feet deep. | Pools present but shallow; between 5–10% of the pool bottom is obscure due to depth, or the pools are less than 3 feet deep. | Pools absent or the entire bottom is discernible. |
| 10 | 7 | 3 | 1 |

**Insect/ invertebrate habitat**

| | | | |
|---|---|---|---|
| At least 5 types of habitat available. Habitat is at a stage to allow full insect colonization (woody debris and logs not freshly fallen). | 3–4 types of habitat. Some potential habitat exists, such as overhanging trees, which will provide habitat but have not yet entered the stream. | 1–2 types habitat. The substrate is often disturbed, covered, or removed by high stream velocities and scour or by sediment deposition. | None to 1 type of habitat. |
| 10 | 7 | 3 | 1 |

**Cover types**: Fine woody debris; submerged logs; leaf packs; undercut banks; cobbles; boulders; coarse gravel; other _________________.