Ministry of Agriculture, Fisheries and Forestry

MILTON PILOT IRRIGATION PROJECT

FEASIBILITY REPORT

Feasibility study, Design and Supervision for an Irrigation System for the Milton Pilot Irrigation Project. This report is undertaken by EnviroPlus Consulting Inc in response to an offer by the Ministry of Agriculture, Fisheries and Forestry on behalf of the Government of the Commonwealth of Dominica & Caribbean Community Centre for Climate Change (5C's).

AUGUST 2011

ENVIRO PLUS CONSULTING INC
Our consultants...your vision

FEASIBILITY REPORT FOR MILTON PILOT IRRIGATION PROJECT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

MEASURES, NOMENCLATURE & ABBREVIATIONS

Measures / Technical Nomenclature

d	:	day
ha	:	hectare
Kg	:	kilogramme
km	:	kilometre
kV	:	kilo Volt
kW	:	Kilo Watt
lpcd	:	litres per capita per day
l/s	:	litres per second
mm	:	millimetre
mm/d	:	millimetre per day
m^3/d	:	cubic metres per day
m^3/h	:	cubic metres per hour
mg/l	:	milligram per litre
Mm^3	:	million cubic metres
DN	:	Diameter Nominal in mm
H	:	hours
L	:	Length
lpcd	:	litre per capita and day
M	:	Meter(s)
m^3	:	Cubic meter
masl	:	meters above sea level
Max.	:	Maximum
Min.	:	Minimum
Nos.	:	Numbers
Q max	:	Maximum Flow
V	:	Volume in m3

MOAF	:	Ministry of Agriculture & Forestry
DOA	:	Division of Agriculture
DOF	:	Division of Forestry

VOLUME 1

CROP WATER REQUIREMENTS

1. INTRODUCTION

1.1 Scope and Objectives of the Project

This feasibility study is undertaken by EnviroPlus Consulting Inc (ECI) in response to an offer by the Ministry of Agriculture, Fisheries and Forestry to investigate, design and present a suitable solution for the provision of irrigation water to facilitate the implementation of a pilot Irrigation project in the location of Milton Estate. The Government of Dominica and the Caribbean Community Climate Change Centre (CCCCC or 5Cs) initiative fund this project to encourage alternate livelihoods for individuals who traditional operated in and around the National Parks boundaries.

Within the present project, the principle objective is to establish a pilot project to inform and encourage adaptation measures to changing climatic conditions among farmers / producers within the Milton area with a consistent and reliable supply of water through the implementation of an irrigation system.

The approach adopted in preparing this report assumes beneficiary's general unfamiliarity with irrigation systems, requiring the presentation of more detailed information.

1.2 Existing Situation

1.2.1 The Project Area Physical Description – Climate, Geology and Soil Type

The Milton Estate is located on the North-Westerly segment of Dominica at the foot hills of Morne Diablotin, the highest peak on the Island (fig 1). The estate, which measures approximately 98 acres (39.66 Ha), was originally owned by the Shillingford family and was traditionally operated mainly as a citrus orchard with other staple intercrop. The estate was subsequently sub-divided in the early 90's to heirs of Cuthbert Shillingford. An overview of the subdivision is annexed 1.

The area is currently still extensively cultivated with citrus intercropped with other cash crops such as yams, pineapples, plantains, dasheen and vegetables in the stated order of economic importance. Production is almost entirely effected "in-field" and thus is entirely dependent on weather conditions with the end result of marked seasonality of production. The currently much publicised aspect of climate change have however significantly affected traditional "in-field" producers' ability to accurately predict the correct planting season for their varied crops. This has led to greater crop failure in the more sensitive shorter term crops with marked unease among producers.

The limited introduction of protected agriculture within the area and in other areas in the country has begun to demonstrate the usefulness of this approach in removing the uncertainty associated in predicting production seasons correctly. In fact seasonality of crops have been eliminated entirely in some cases, as this approach offers the opportunity to provide a modified environment that favours production especially in the case of vegetables. The modification of the cropping environment therefore necessitates that key inputs such as water, be readily available in sufficient quantities, to be applied to the plant when required. Thus, irrigation system is viewed as being a very important to in maintaining food security within the current changes in climate.

1.2.2 Climate

The prevailing weather patterns within the Commonwealth of Dominica can be described as being distinctly wet (rainy season) or dry (dry season) and traditionally occurred during the period of July to December and February to June respectively. Recent climatic changes thought to be the effects of global warming, have significantly altered the timing of occurrences of the seasons, essentially resulting in the inability to accurately make predictions and plans to mitigate these seasonal impacts. Annual coastal rainfall averages in Dominica varies from about 1,500 mm (59”) to 3,700 mm (145.6”), but can reach 7,620 mm (300”) in the central mountains. An average of 6350 mm (250”) is estimated for the project site.

Average annual temperature is about 27°C, with dry season temperatures reaching a high of 30°C (23 to 30°C in June). Temperatures during the wet season are not much lower, ranging from 20 to 29°C in January and never falling below 18°C.

Milton, being located at the windward foothills of Morne Diablotin experiences higher rainfall level than that recorded on the coastline. The annual distribution of this rainfall is however poor, thus leading to periods of shortages in the supply of crop water. Unfortunately, there are no agro-meteorological recording stations within or close to the project area. This will therefore necessitate extrapolation of data from a suitable site.

1.2.3 Geology

Geologically, the upper catchment of the Dublanc River Milton area flanked by the in the south is formed from pyroclastic aprons of block and ash flow deposits and andesite lavas, which are present around the palean andesite/dacite dome of the summit of Morne Diablotins. The lower slopes, including the agricultural production area of Milton are formed from older Pliocene assorted volcanic rocks, including mafic flow rocks (see fig 2).

Progressively, the rivers flowing off the slopes of Morne Diablotin have eroded very deep valleys leaving steep sided and well-defined ridges flanked by the tributaries and the main Dublanc and Point Round Rivers to the South and North respectively. Communications, roads, settlements and proposed pipelines will all follow the linear alignment of the main ridges.

1.2.4 Soils

The soils found in the Milton area are predominantly Allophanoid Latosolics with distinct soil developments and soil layering. Lang, 1967, indicates reasonably fast drying soils, with a high degree of weathering and medium organic matter accumulation. From visual inspections during field surveys conducted, soils are relatively fertile and crop production is effected with sound soil erosion, and water management practices.

1.3 Tourism development

Access to the scenic Syndicate waterfall located on the Dublanc River and the summit of Morne Diablotin; the tallest peak on the island is through the Milton Estate. Significant potential to develop the agro-tourism in the area therefore exists. The establishment of small vending sheds along the main road offering various craft and agricultural produce is one area currently being developed.

The higher ridges within Milton also provide a clear and serene view of the Caribbean Sea and the surrounding mountain peaks, which makes it an ideal location for resorts and retreats. It is however important to review the planning regulations relating to the conservation of biodiversity and to ensure that any development is carefully monitored prior to undertaking any major development.

1.4 Design criteria required for the Irrigation Project

Following the identification of the main physical characteristics of the Milton Project area the irrigation system design will be based on:

- Command area to be irrigated
- Estimated Crop Water requirements
- Average monthly Rainfall
- System Peak water demand calculations
- Catchment characteristics
- Catchment yield estimations
- 1 in 50 year Peak flood flow and 1 in 5 year low flow calculations
- Survey data of supply pipeline
- Survey data from proposed distribution within area to be irrigated
- Standard design criteria for intake structures and conveyance pipelines

The design principles adopted will now be described and presented in the following sections of the report.

FIG 1: Map of Dominica showing location of the Milton Project Area

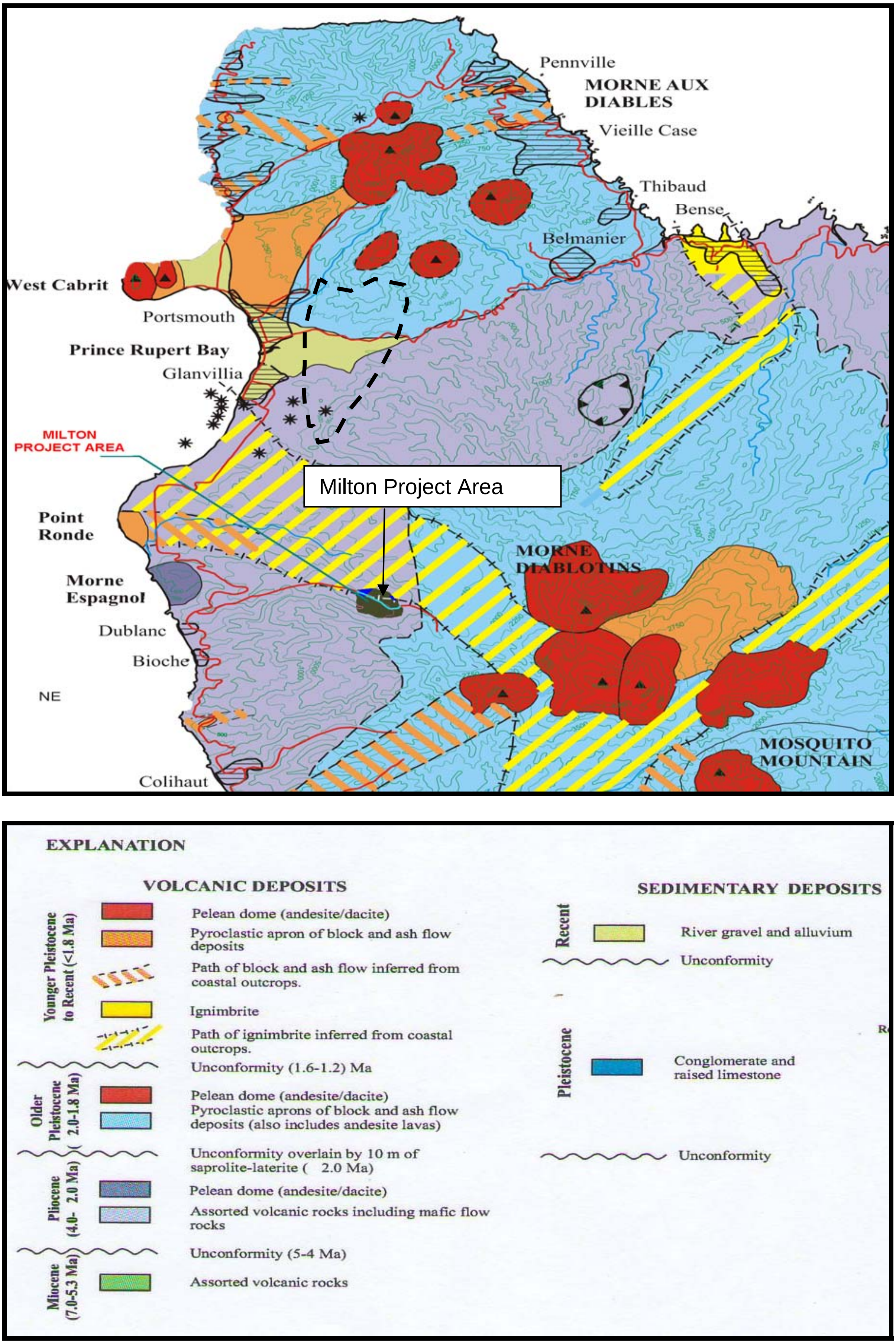


FIG 2: Geological Map of North East Dominica

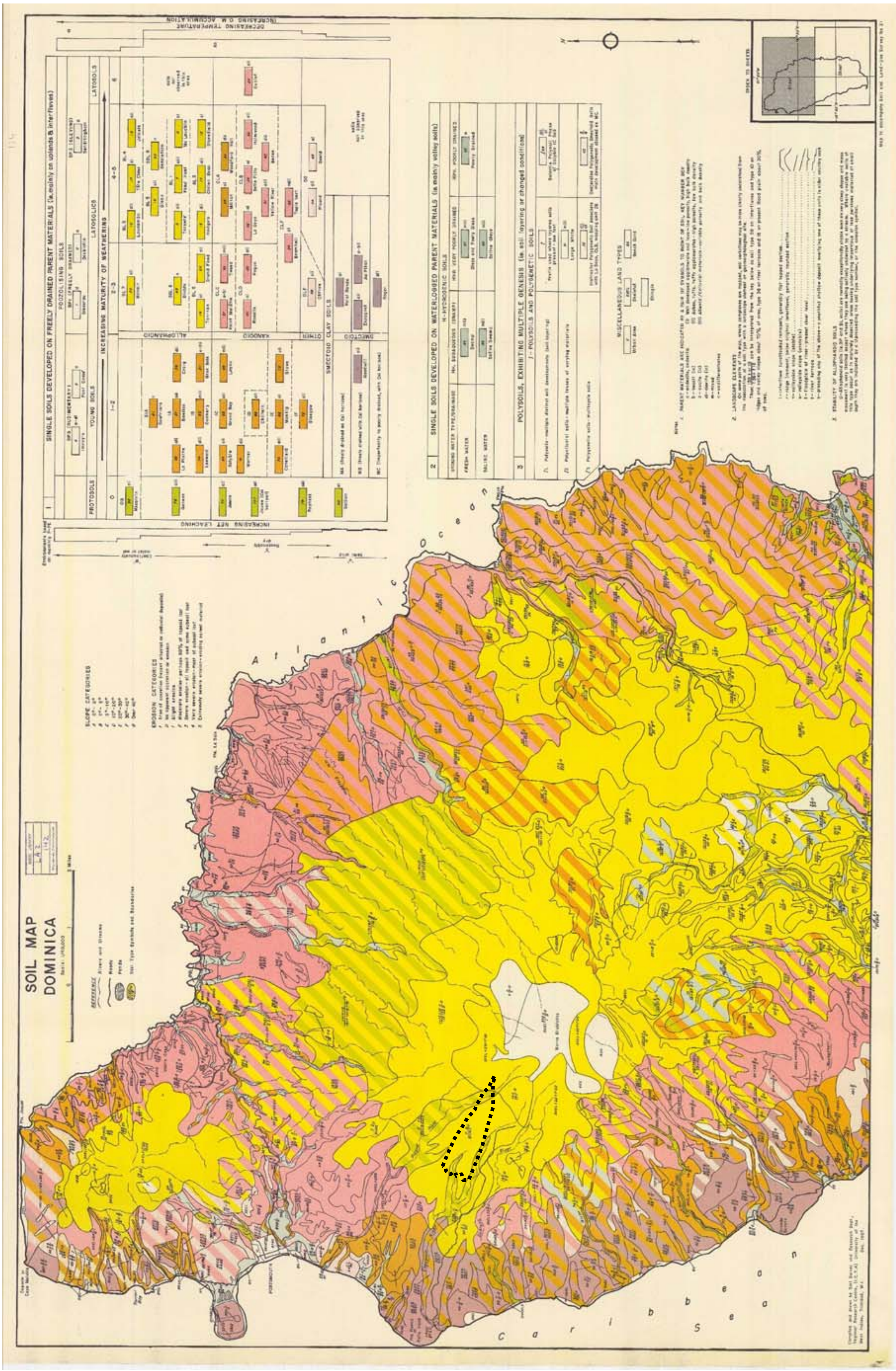


FIG 3: Soil Classification Map of North-West Dominica

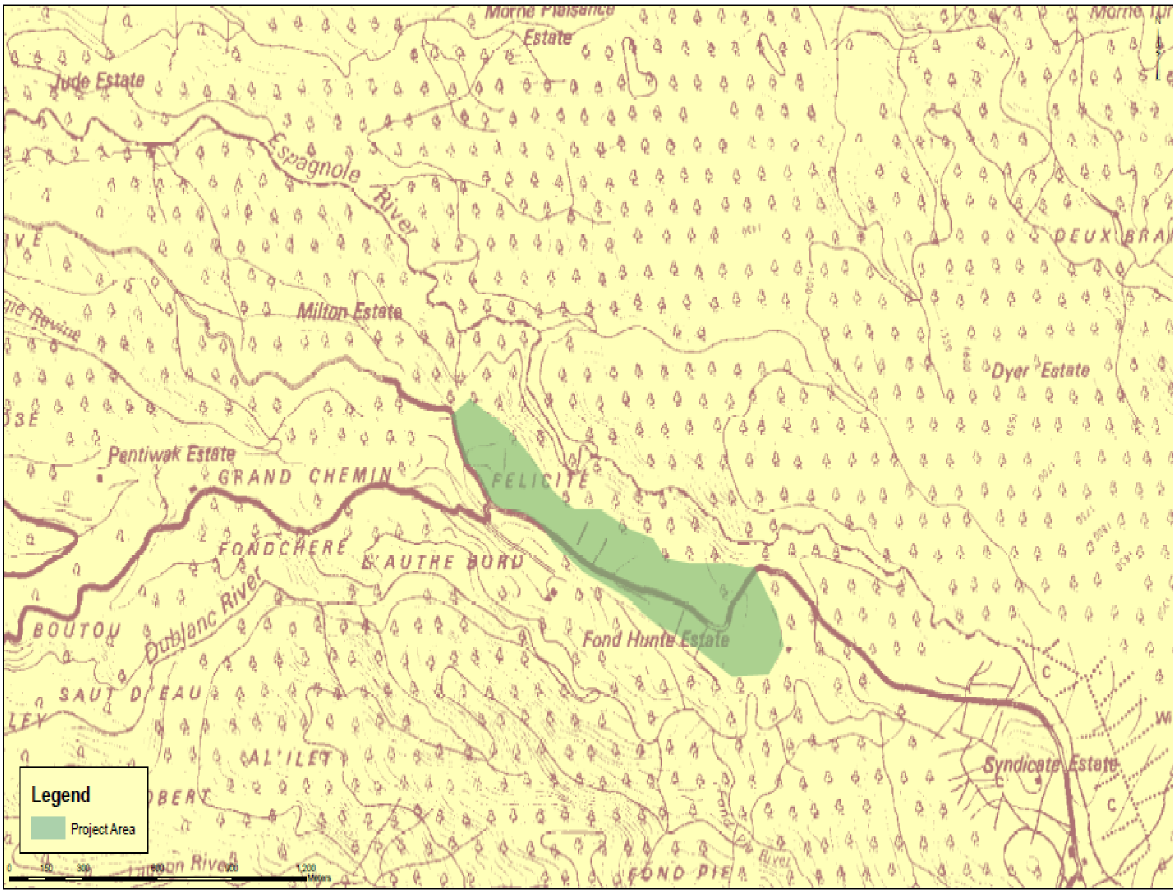


FIG 4: Milton Agricultural Production areas

2. CROP WATER REQUIREMENTS

2.1 Plant demand for water

The essential inputs to the growth of vegetation are plant nutrients, water and energy. Water has several important functions in plants to include; structural, photosynthesis, solvent and cooling and is therefore critical to crop production.

Water constitutes over 80% of most living plant material. In dry grains, it can be as low as 5%, but in actively growing tissue, it is often over 95%. Most Plants can only tolerate small variations in water content and reduction as little as 20% will often lead to a complete cessation of the growing processes. Fig 5 displays the main features of the plant water system.

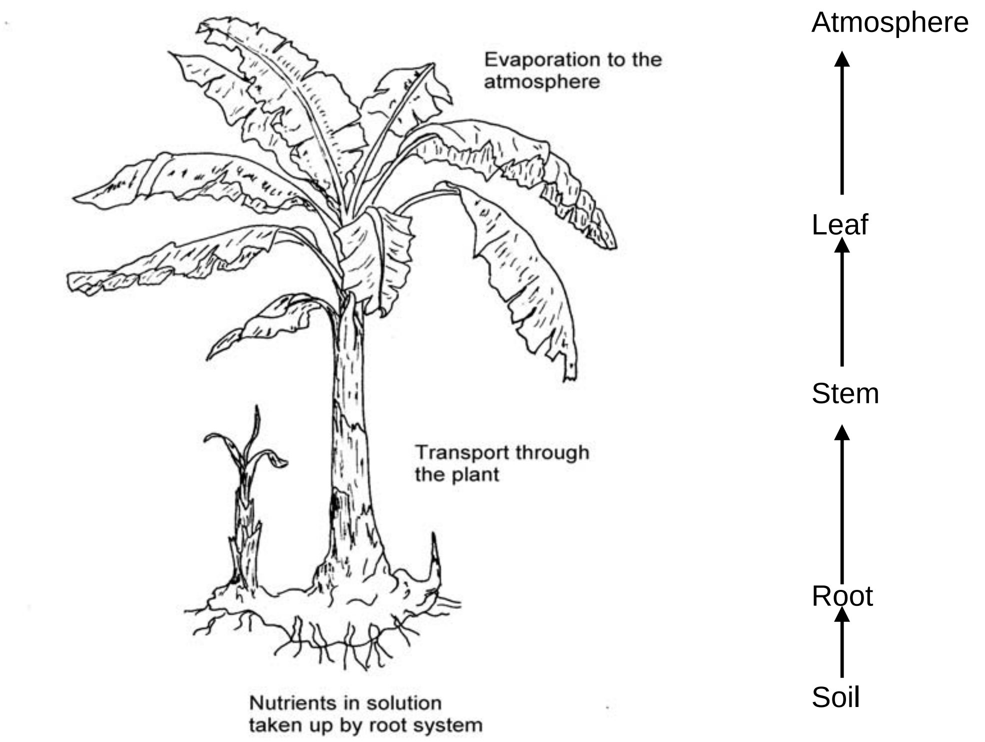


FIG 5: Main features of a plant's water system

2.2 Evapotranspiration

2.2.1 Terminology

The demand for water is a function of the plant type, climate and growth environment. The following sections will now be devoted to some of the common terminology and principles used in the assessment of water demand in relation to the determination of plant water requirement at Milton.

2.2.1.1 Evaporation

Within the report, Evaporation describes the conversion of liquid water to vapour. It may take place from open water surfaces, the soil surface or from plant leaves (intercepted water). The rate of evaporation is primarily controlled by weather factors.

2.2.1.2 Transpiration

The plant roots extract water from the soil to live and grow. The main proportion of this water escapes to the atmosphere as vapour through the plant's leaves and stems; a process called transpiration.

The amount of water used by plants for transpiration is expressed in millimetres of water per day (mm/day) throughout the report.

2.2.1.3 Evapotranspiration

The evapotranspiration of a crop is the total amount of soil water used for transpiration by the plants and evaporation from the surrounding soil surface. It is the total amount of water utilized by the crop and its environment.

Evapotranspiration is expressed in millimetres of water used per day (mm/day) in the report.

2.2.2 Factors influencing Crop Evapotranspiration

A summary of factors characteristic to the project area, affecting crop evapotranspiration are listed in table 2. These are separated into climatic, crop and edaphic factors.

Table 1: Factors affecting Crop evapotranspiration

Factor	**Effect on crop evapotranspiration**	
	High	**Low**
Climate	Hot Dry Windy No Clouds	Cool Wet No Wind Cloudy
Crop	Mid/late season Dense plant spacing	Initial or ripening Wide plant spacing
Soil Moisture	Moist	dry

2.2.3 Reference evapotranspiration (ETo)

The rate of evapotranspiration at a given place and time depends upon the interaction of the weather and the crop. The definition of a reference condition can therefore describe the influence of the weather.

The FAO definition of "reference crop evapotranspiration" is the evapotranspiration rate from an extended area of green grass or alfalfa cover, 8-15cm tall, of uniform height, actively growing, completely shading the ground and not short of water.

ETo reflects the evaporative demand of the atmosphere as a function of the weather. Table 2 details potential evapotranspiration calculated using the Penman-Monteith formula and climatic data recorded at the Melville Hall Met Station.

2.2.4 Potential Crop evapotranspiration (ETcrop)

The potential evapotranspiration for a given crop, ETcrop is the sum of the crop transpiration and soil evaporation for a healthy crop, at a particular stage of growth and not short of water. (ETcrop = ETo x Kc where Kc is the crop coefficient)

Typical values of ETo and ETcrop for Bananas and fresh Peas (selected based on their higher water requirement among the variety of crops cultivated within the project area) utilizing Climatic Data for Melville Hall Airport, Dominica are presented in Table 4 below. The information presented indicates that the average water requirement based on average daily Etc is higher for Bananas as compared to fresh peas. This further justify the approach of utilizing crop water requirement for Bananas as the basis for determination of system design volumes, confident that a system so designed will adequately provide for the protected agricultural system envisaged or the integrated cropping pattern that is characteristic of agriculture locally. This approach is particularly desirable, since crop production decision is solely producer controlled.

Table 2: Reference Average Monthly Evapotranspiration ETo calculated using Meteorological data from the Melville Hall Met station.

Month	Temperature Min °C	Temperature Max °C	Humidity	Wind km/day	Sunshine Hours	Radiation MJ/m2/day	Eto mm/day
January	22.30	29.70	78.00	116.00	7.90	18.10	4.42
February	23.10	29.20	79.00	155.00	7.40	18.90	4.85
March	22.60	29.60	81.00	136.00	7.40	20.40	5.41
April	22.90	30.20	74.00	117.00	8.40	22.50	5.62
May	24.50	30.20	81.00	122.00	8.30	22.10	5.64
June	24.70	30.90	75.00	142.00	6.40	19.00	5.49
July	25.20	31.10	79.00	126.00	8.70	22.50	5.38
August	24.00	31.40	79.00	73.00	7.80	21.40	5.53
September	22.70	31.00	80.00	75.00	6.50	19.00	5.00
October	24.00	31.50	78.00	62.00	7.70	19.60	4.55
November	24.50	30.50	77.00	93.00	8.00	18.50	4.09
December	23.00	30.60	79.00	96.00	7.00	16.40	3.89
Year	**23.63**	**30.49**	**78.33**	**109.42**	**7.63**	**19.87**	**4.99**

Table 3: ETo and ETcrop for Banana based on Climatic data for Melville Hall

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Reference ETo	4.42	4.85	5.41	5.62	5.64	5.49	5.38	5.53	5	4.55	4.09	3.89
crop factor kc	1	1	1	1	1.2	1.2	1.1	1.1	1	1	1	1
ET crop mm/day	4.42	4.85	5.41	5.62	6.77	6.59	5.92	6.08	5.00	4.55	4.09	3.89

Table 4: ETo and ETcrop for fresh peas based on Climatic data for Melville Hall

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Reference ETo	4.42	4.85	5.41	5.62	5.64	5.49	5.38	5.53	5	4.55	4.09	3.89
crop factor kc	0.65	1.05	1.1	0.65	1.05	1.1	0.65	1.05	1.1	0.65	1.05	1.1
ET crop mm/day	2.87	5.09	5.95	3.65	5.92	6.04	3.50	5.81	5.50	2.96	4.29	4.28

Note: Crops such as bananas are planted and harvested throughout the year in Dominica; the crop factor should therefore be kept at 1.2 to give a more realistic value of ETcrop for the whole of the irrigation area.

2.2.5 Actual Evapotranspiration (ETa)

Actual evapotranspiration (ETa) depends on the weather and plant stomata resistance. Soil water content depletion, through the process of evapotranspiration results in the closure of stomatal pores, increasing resistance to further water loss. Under constant weather conditions therefore, the actual evapotranspiration depends on the soil water content. Consequently, it would be higher immediately after irrigation/rainfall (when water is freely available to the plant and the soil is wet) and would decline over time as the soil dries.

2.3 Soil and Water

2.3.1 Infiltration rate

After rainfall or an irrigation event, water seeps/enters into the soil via a process called infiltration. The infiltration rate of a soil is the velocity at which water can seep into it, and the depth (in mm) of water layer that the soil can absorb in an hour quantifies it. For efficient irrigation, drainage and erosion control, it is necessary to know the rate at which water will move into different soils under varying conditions. The application of water to a soil at a rate greater than the infiltration rate, results in ponding on the surface or / and runoff, causing erosion.

2.3.1.1 Factors affecting the infiltration rate

The infiltration rate of soils depends on factors that are constant, such as soil structure. It also depends on factors that vary, such as soil moisture content.

2.3.1.1.1 Soil Texture

Coarse textured soils have large particles in between which are large pores. Fine texture soils have mainly small particles in between which are small pores.

In coarse soils, the rain or irrigation water enters and moves more easily into the characteristic larger pores; it takes less time for the water to infiltrate into the soil. Infiltration rates are therefore higher for coarse structured soils than for fine textured soils.

Water infiltrates faster (higher infiltration rate) when soil is dry than when wet. Consequently, after an irrigation or rainfall event, the water at first infiltrates easily, but as the soil becomes wet, the infiltration rate decreases. For most soils, the infiltration rate will stabilise after a period, a factor known as the terminal infiltration rate.

Table 5 displays typical values of terminal infiltration rates for the main soil types.

Table 5: Typical values of terminal infiltration rates

Soil type	Terminal infiltration rate mm/hr
Sands	>20
Sandy & Silty soil	10-20
Loams	5-10
Clayey soils	1-5
Sodic clay soils	<1

The infiltration rate of a soil is altered by adopting practices that affect soil structure such as cultivation and compaction.

The soils observed in the Milton area during the field surveys appeared to be predominantly Clay loams, with differing degrees of infiltration depending on the cultivation practices implemented. Infiltration rate were determined using a Turf Tec double ring infiltrometer and are recorded in table 6. Methodology employed included the recording of measurements after filling the rings 3 times, to ensure the observance of saturated flow through the soil pores. Fig 6 is a photo of soil infiltration measurement at Milton. Terminal infiltration rates observed in cultivated areas were in the range of 6 – 10 mm /hr, consistent with the prevalent soil type indicated by the soil map description-typical loam.

Table 6: Observed infiltration rates within the project area

Location	Coordinates	Time (sec)	Inflitration depth (mm)	Inflitration rate (mm/sec)
M1	N 15°31.370'	161	25.40	0.16
	W 061°26.395'	192	25.40	0.13
		218	25.40	0.12
Ave				**0.14**
M2	N 15°31.330'	78	12.70	0.16
	W 061°26.314'	75	6.35	0.08
		60	9.53	0.16
		180	6.35	0.04
Ave				**0.11**
M3	N 15°31.290' W 061°26.191'	250	50.80	0.20
		60	6.35	0.11
		60	9.53	0.16
Ave				**0.16**

FIG 6: Measurement of Infiltration rate at Milton with Turf Tec double ring infiltrometer

2.4 Soil Moisture Conditions

2.4.1 Soil Moisture Content

The soil moisture content indicates the amount of water present in the soil. It is expressed as the amount of water (in mm of water depth) present in a depth of one metre of soil in this report.

2.4.2 Saturation

During a rain shower or irrigation application, the soil pores are progressively filled, until saturated with water. This condition significantly reduces the volume of air left in the soil. Many crops cannot withstand saturated soil conditions for a period of more than 2-5 days. This is especially true of many of the major crops presently being cultivated within the project area namely bananas, plantain, tannia, yams and vegetables, with dasheen being the sole exception. Fortunately, the period of saturation of the topsoil usually does not last long. After the rain or irrigation has stopped, part of the water present in the larger pores will move downward through drainage or percolation.

Coarse textured (sandy) soils, drains within a few hours of becoming saturated. In finer textured (clayey) soils, drainage may take several days. These characteristics are significant in the planning of drainage systems to remove excess water within the project area in cases where excess is applied. Notwithstanding the design of a drainage system not being part of the TOR, necessary contingencies is required to address an adequate drainage system to safely and efficiently remove excess water that will invariably occur.

Most farms within the project area contain existing farm drains for the removal of excess surface water. The missing link is a network of main drains into which the on-farm drains empties.

2.4.3 Field capacity

After the drainage has stopped, the large soil pores are filled with both air and water while the smaller pores are still full of water. A stage described as field capacity- The water and air content of the soil is considered ideal for crop growth.

2.4.4 Permanent Wilting Point

Gradually, the water stored in the soil is taken up by the plant roots or evaporated from the topsoil into the atmosphere (fig 5 & 7). If no additional water is supplied to the soil, it gradually dries out.

The drier the soil becomes, the more difficult it is for the plant roots to extract it. At a certain stage, the uptake of water is not sufficient to meet the plant's needs. The plant looses freshness and wilts; the leaves change colour from green to yellow. Finally the plant dies.
Permanent wilting point identifies the soil water content at the stage where the plant dies.

2.4.5 Available Water Content

The soil can be compared to a water reservoir for the plants. When the soil is saturated, the reservoir is full. When the initial water has drained away, the soil is at field capacity. The plant roots draw water from what remains in the reservoir. When the soil reaches permanent wilting point, the remaining water is no longer available to the plant.

The amount of water actually available to the plant is the amount of water stored in the soil at field capacity minus the water that will remain at permanent wilting point.

Available water content = water content at field capacity – water content at permanent wilting point

The available water content depends greatly on the soil texture and structure. Table 7 gives a range of values for different soil types.

Soil characteristics: field capacity, permanent wilting point and available water content are constant for a given soil.

Table 7: Available water content ranges for different soil types

Soil Type	**Available water content in mm water depth per m soil depth (mm/m)**
Sand	25 to 100
Loam	100 to 175
Clay	175 to 250

Subtle variability within the project area is however anticipated, based on observed minor variability of soil type. This variability is however insignificant based on the proportion of the predominately loam soils on the site, (fig 28). A survey of the locale revealed an evidence of a higher percentage of sticky clay within depression. This is most likely directly linked to the scouring of top soil / organic matter to expose less mobile clay particles lower in the profile.

Soil characteristics are critical in designing a suitable irrigation system for soil based production systems. The ultimate aim of the design is to provide the optimum conditions for plant growth and development by maintaining the soil moisture content at levels where water is readily available. It is envisaged that this condition will encourage sustained investment in food production.

Based on the Crop water requirements for the Milton project area, and the rainfall records from Melville hall and Canefield meteorological station, the main design parameters for the Irrigation system design were established.

3. IRRIGATION

3.1 Purpose of Irrigation

The purpose of Irrigation is to provide a sufficient amount of water to maintain an ‘optimum’ soil moisture environment for the plant, providing the best growing conditions and maximum yields for any given crop.

3.2 Irrigation Scheduling

The design of an irrigation system provides a certain capacity that is usually designed to meet the peak irrigation water requirements of the crop. In the day-to day operation of the system we need to determine:

- When to apply water?
- How much water to apply?

Providing answers to these questions is the major issue of irrigation scheduling, and is the key to operating an effective, efficient and successful system. The approach adopted for design evaluation assumes that the crop produced requires its maximum water requirement met within a 4.07- hour day.

The key to irrigation scheduling is to apply water often enough to prevent the plants suffering from drought and to apply as much as the plants have used since the previous irrigation. This is illustrated in Fig 8

3.3 Limits of acceptable soil water content

The upper limit is field capacity: Any more water than this will drained out of the soil profile, runoff at the surface or may cause waterlogging problems.

The absolute lower limit is the permanent wilting point, however the plant will suffer stress long before this is reached, and therefore the practical lower limit is the easily available water capacity, i.e. that amount of water that can be extracted without stress.

This will depend on

- The soil (total available water capacity per m of soil
- Crop type (fraction of Available Water Content that is easily available)

- Root depth (depth of soil that can be exploited by the plant)

RAW = p x D x Sa

Where

RAW	readily available water (mm)
p	allowable depletion (fraction)
D	root depth (m)
Sa	available water capacity (mm/m)

3.4 How much to Irrigate

How much and how often water has to be applied depends on the irrigation water need of the crop. Crop water requirement less effective rainfall, given crop production takes place in open field, defines irrigation water need. The project however foresees the implementation of undercover production systems and so irrigation depth with this scenario is equivalent to crop water requirement. Irrigation water needs is expressed in mm/day or mm/month in this report.

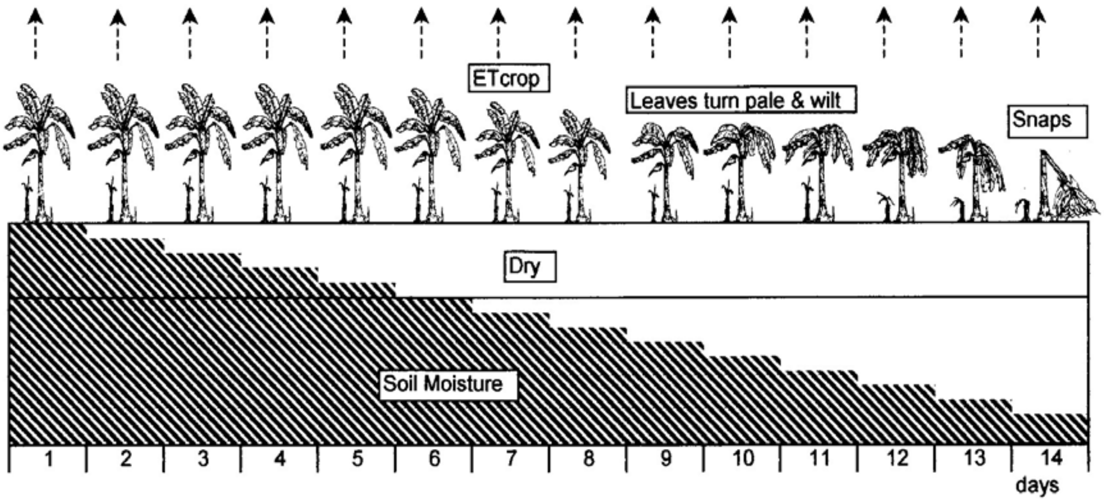
3.5 Water Supply and Crop Yield

Bananas and plantains (also many other fruiting crops) require an ample and frequent supply of water as water deficits adversely affect crop growth and yields. The establishment period and the early phase of the vegetative growth determine the potential for growth and fruiting in most plant species. An adequate water and nutrient supply to the plant is essential during this period. Water deficits in the vegetative period affect the rate of leaf development, which in turn can influence the number of flowers and fruit.

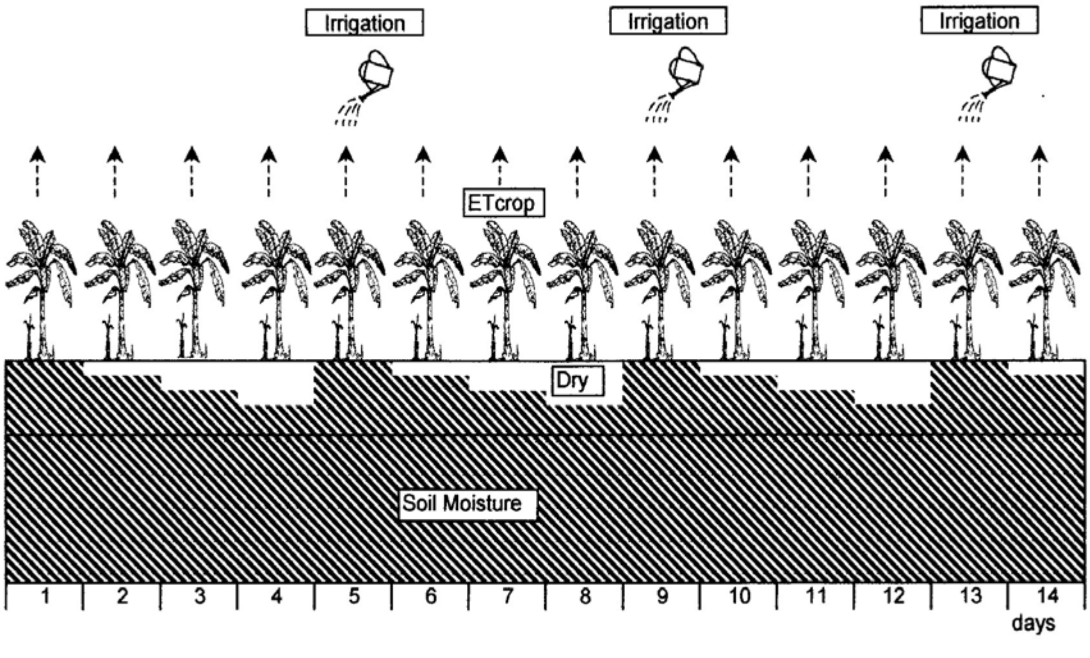
Water deficits in the yield formation period affect both the fruit size and quality. A reduced leaf area will reduce the rate of fruit filling; this leads, at harvest time, to the fruit being older than they appear to be and consequently the fruits are liable to premature ripening during transportation and storage.

The interval between irrigations also has a pronounced effect on yield, with higher yields achieved when intervals are short.

If it is assumed that the soil is at field capacity on day 1, the crop will have no difficulty in taking up water for the first couple of days. As more and more days pass without irrigation, however, the crop will have more and more difficulty in taking up water.



In the absence of rainfall and if no irrigation water is applied, leaves turn pale and wilt, smaller bunches develop, less hands, fewer fingers. If the dry period is prolonged the plants eventually die.



If irrigation water is applied regularly, the plants do not suffer from water shortage. This produces taller plants, with greater leaf area and results in earlier shooting and higher yields.

FIG 7: Comparison between irrigated and non-irrigated bananas

3.6 Rainfall within project area

Given that there are no actual agro-met data for the project area, the rainfall records from Melville Hall and Canefield meteorological station were analysed and the former chosen as the closest representative rainfall gauging station (with the longest period of records) to the project site. Notwithstanding the location of Balvine rainfall station within closer proximity to the Milton site, the coastal microclimate that predominates in this locale (low altitude, mild sea breeze etc.) contrasts distinctly from the high elevation stronger oceanic mountain breeze that is characteristic of the Milton site. Further, only rainfall is recorded at Balvine, for a relatively short period compared to the Melville Hall site. Melville Hall, while relatively close to the coastline, is subject to the southeasterly trade winds that dominates the weather systems during the traditional hurricane / rainy season. The rainfall and climatic conditions generated is more closely related to that observed at the higher altitude peaks of Milton, where humid oceanic breeze that is forced to rise rapidly relatively close to the coastline also give rise to rainfall than that observed at Canefield or Balvine recording station. Lang, 1967 supports this view and further suggests that local climate is closely linked to the topography of the island with rainfall increasing and temperature falling with increasing elevation. He postulated that distribution was not symmetrical about a line joining the high points of the islands with leeward rainfall being generally lower and temperatures higher than at the same elevation on the windward side.

A combination of anecdotal information and hind casting suggests that due to the elevation of the project area, (>1850 m), the difference in rainfall volume experienced as compared to Canefield is significantly higher than that for Melville Hall.

As it relates to rainfall distribution, data from both recording stations demonstrates the inability to meet full daily crop requirements for a number of days significant enough to affect crop production, during the typical dry period of late December-June. This consideration was therefore was assessed as non-critical in the selection decision to extrapolate data from Melville Hall for the purpose of this exercise.

A total set of daily records from 1969 through to August 2009 have been analysed for the purposes of assessing the monthly average and the monthly 20 percentile (representing the values for a 1 in 5 year drought). Data presented in table 3.2.

Monthly average rainfall data for the Melville Hall Met station is charted in fig 8 together with the estimated 1-in 5 yr drought data. The distribution of annual rainfall for Melville Hall, Dominica, demonstrates a pattern where the dry season extends from January through to June, followed by a much wetter season from July through to December. This corresponds to the heavy rainfall associated with the hurricane season.

In the calculation of actual water deficit to be supplied by irrigation, due consideration must be given to the fact that not all rainfall is utilized by the plant. The portion used, is referred to as effective rainfall. Fig 9 displays average monthly effective rainfall and rainfall during the 1 in 5-year drought calculated utilizing the US Soil Conservation Service method.

Table 8: Melville Hall Monthly Rain data (1969-2009) & Balvine Ave. Rainfall (2007 – 2009)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1968										139.95	109.98	343.92	
1969	114.05	131.57	79.25	145.80	334.26	361.19	233.43	228.60	339.85	476.25	582.17	279.40	**3305.81**
1970	67.31	60.45	67.82	67.56	215.14	326.64	406.40	320.29	369.32	536.70	430.28	484.63	**3352.55**
1971	96.52	85.34	42.16	49.78	137.67	117.09	176.53	254.76	116.33	178.82	64.26	255.02	**1574.29**
1972	169.42	183.39	256.54	259.08	155.45	220.22	104.65	403.61	359.41	320.29	266.19	224.79	**2923.03**
1973	120.40	91.69	106.17	93.47	36.58	227.33	143.76	309.37	371.86	179.58	156.21	116.84	**1953.26**
1974	245.62	148.59	187.20	67.56	163.58	172.21	72.39	128.02	468.38	322.33	226.57	161.29	**2363.72**
1975	113.54	93.22	161.54	43.69	89.41	93.47	59.69	163.32	139.19	470.15	337.06	506.73	**2271.01**
1976	214.12	163.58	80.77	82.04	184.91	159.00	135.38	158.24	273.05	532.89	277.37	560.83	**2822.19**
1977	61.98	28.45	72.14	131.06	116.84	71.63	136.14	284.73	328.42	452.88	439.42	110.24	**2233.93**
1978	284.73	29.72	109.98	192.53	204.47	116.84	175.51	232.66	251.97	338.84	184.66	101.60	**2223.52**
1979	59.69	113.28	218.19	30.48	205.49	439.67	234.70	378.21	499.36	469.65	651.26	227.58	**3527.55**
1980	63.75	133.60	51.82	120.65	86.61	185.67	208.28	284.23	241.81	291.34	311.66	166.12	**2145.54**
1981	208.28	157.73	60.71	762.51	420.12	191.01	218.95	405.89	332.23	262.13	214.38	487.43	**3721.35**
1982	114.30	175.77	83.31	132.08	566.17	180.34	364.49	251.97	244.09	226.57	404.62	618.24	**3361.94**
1983	58.17	129.79	138.68	52.83	349.50	133.60	201.42	204.72	311.66	140.97	97.54	128.78	**1947.67**
1984	125.48	70.36	198.37	96.01	78.49	158.50	228.85	81.79	330.20	366.01	693.93	161.80	**2589.78**
1985	98.30	67.06	153.67	97.79	91.44	59.18	187.96	177.80	272.29	508.00	472.69	111.51	**2297.68**
1986	200.66	32.51	170.94	223.01	251.97	141.22	144.53	234.19	263.14	243.59	699.01	197.10	**2801.87**
1987	92.46	51.31	66.80	29.97	815.59	424.18	158.24	236.47	120.40	389.13	721.87	140.72	**3247.14**
1988	135.38	98.30	173.23	152.91	197.61	246.89	273.30	442.47	370.08	344.42	316.23	140.21	**2891.03**
1989	68.58	196.60	260.60	130.05	55.12	43.18	273.30	411.23	545.34	277.11	148.34	163.83	**2573.27**
1990	97.79	122.17	102.36	296.93	191.77	121.41	151.38	205.49	210.31	360.68	291.85	213.11	**2365.25**
1991	69.09	103.12	84.33	116.84	63.25	247.90	172.97	180.09	247.40	93.98	490.73	192.28	**2061.97**
1992	147.83	77.22	50.80	153.92	239.27	247.90	247.40	315.47	345.44	141.73	283.46	189.48	**2439.92**
1993	155.96	170.18	109.22	143.76	541.53	174.50	210.82	259.59	465.07	239.52	375.41	207.01	**3052.57**
1994	80.01	89.41	27.69	49.28	194.31	88.90	57.40	181.36	370.84	269.24	246.38	295.40	**1950.21**
1995	217.17	106.93	295.91	177.55	68.33	58.67	294.64	406.91	551.94	240.79	201.42	218.44	**2838.70**
1996	126.75	76.96	173.74	113.28	114.81	149.35	328.42	170.69	568.96	372.62	279.15	279.15	**2753.87**
1997	179.58	86.11	123.70	18.80	277.37	129.29	338.07	208.03	243.84	309.37	150.11	130.56	**2194.81**
1998	248.92	33.27	65.28	227.84	292.10	254.00	305.56	256.79	260.86	644.91	356.62	372.62	**3318.76**
1999	204.72	103.12	168.40	215.90	75.95	215.39	232.16	140.46	184.91	351.28			
2000	213.60	90.10	98.60	76.60	139.00	106.00	189.90	236.60	241.20	273.40	460.40	122.40	**2247.80**
2001	82.70	97.10	50.30	75.00	12.10	129.20	314.80	257.20	134.70	522.00	109.30	631.40	**2415.80**
2002	95.70	118.80	104.20	467.10	339.10	115.00	210.40	168.60	167.30	225.60	254.30	99.80	**2365.90**
2003	83.00	57.20	35.10	174.90	139.20	346.50	309.60	328.70	146.90	347.30	526.70	223.90	**2719.00**
2004	148.70	106.40	141.70	76.40	627.70	117.10	269.20	231.40	744.50	182.70	912.00	174.00	**3731.80**
2005	168.40	196.50	31.20	60.90	208.30	369.30	231.80	229.00	150.40	352.50	320.30	99.10	**2417.70**
2006	94.30	51.60	94.80	72.10	172.30	350.60	293.30	201.10	192.70	477.10	243.00	311.70	**2554.60**
2007	174.00	53.60	79.90	107.50	81.20	153.80	141.00	409.60	263.30	586.50	123.20	159.40	**2333.00**
2008	129.80	134.90	108.60	87.50	159.10	154.80	206.10	170.70	551.00	368.70	228.40	130.30	**2429.90**
2009	152.20	88.90	48.00	267.80	310.10	256.30	162.20						
Average	136.17	102.58	115.46	144.90	219.59	191.59	214.76	253.76	314.75	342.19	347.40	240.89	**2623.58**
%age	5.19	3.91	4.40	5.52	8.37	7.30	8.19	9.67	12.00	13.04	13.24	9.18	
Lowest	58.17	28.45	27.69	18.80	12.10	43.18	57.40	81.79	116.33	93.98	64.26	99.10	**1574.29**
20% ile	82.70	60.45	66.80	67.56	86.61	116.84	144.53	176.38	191.14	236.93	184.66	140.21	**1554.82**
Balvine													
Average	214	116	151	117	99	184	226	277	287	316	143	204	2334
% age	9.2	5.0	6.5	5.0	4.2	7.9	9.7	11.9	12.3	13.5	6.1	8.8	
20%ile	170.4	91.4	67.8	91	42.4	119.6	196.2	216.4	261	250.8	112.2	168.4	1787.6

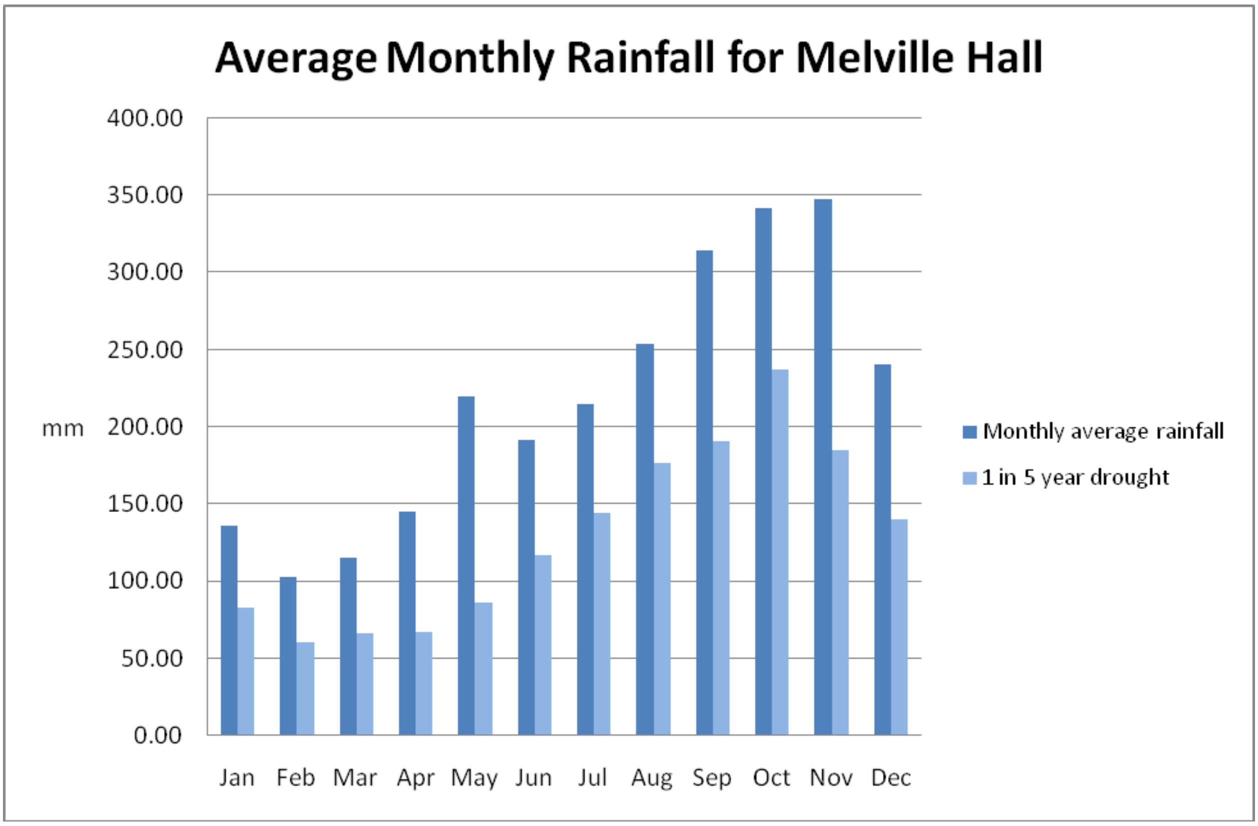


FIG 8: Average Monthly Rainfall for Melville Hall (1968-2009)

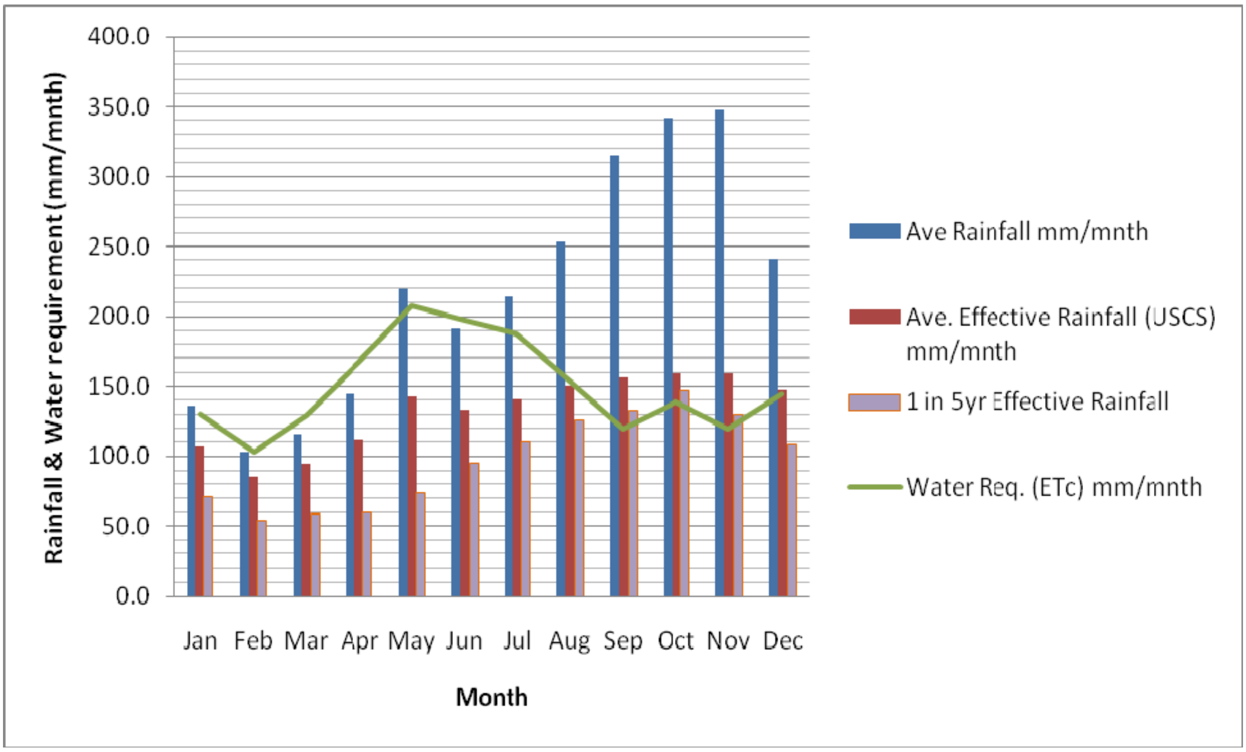


FIG 9: Monthly Average Effective Rainfall and 1 in 5 yr Average Effective Rainfall in mm / month

Based on the monthly average banana plant water requirement (banana having a high water requirement) displayed in figure 9 above, there is insufficient rainfall during January to July (included) for optimal growing conditions. During a 1 in 5 year drought however, this period is extended through to August. To avoid severe wilting and crop loss during these periods, supplementary water applied through an appropriate irrigation system is essential.

In the case of protected agriculture production such as Green/shade Houses, rainfall is excluded completely from the production area and thus irrigation is required year round.

3.7 Irrigation System Design

The evapotranspiration calculated for banana, the characteristics of protected agriculture in Dominica and the analysis of monthly rainfall data clearly indicating the need for irrigation in the Milton area. The next stage is to choose the most convenient means of conveying and distributing the water within the command area.

The main components of an irrigation system includes, an intake structure or pumping station, a conveyance system, a distribution system, a field application system supported by a drainage system.

- The intake structure or pumping station, directs water from the source of supply, such as a reservoir or a river, into the irrigation system
- The conveyance system assures the transport of water from the main intake structure to the area to be irrigated.
- The distribution system assures the transport of water through the project area
- Field application system assures the application of water within the fields
- The drainage system removes the excess water from the fields.

The two most commonly used systems in Dominica are low impact under canopy sprinklers and Trickle or Drip Irrigation.

3.7.1 Sprinkler Irrigation Systems

Sprinkler irrigation is a method in which water is distributed under pressure through a pipe system and applied to the field using spray devices or sprinklers to simulate rainfall. There are numerous different systems worldwide to match the various crop, soil, climate and site constraints, coupled with different water, labour and capital availabilities.

The most commonly used sprinkler system in Dominica is the Solid-set or permanent system (see fig 10).

The basic components of this type of sprinkler system include:

- Sprinkler/Spray nozzle: Sprinklers exist in a wide range of sizes from garden sprinklers for lawns, small sprinklers for vegetables to big guns for banana fields. The big guns are usually overhead sprinklers and the smaller sprinklers for under canopy irrigation.

- Lateral Tube: These are generally manufactured from Polyethylene and deliver the water to the sprinkler heads at the required operating pressure.

- Sub-Main Pipe: delivers water from the control head to the lateral tube and can either be Polyethylene or UPVC.

- Control Head: comprising control valves, pressure and flow regulators, flow control valves and secondary filtration unit.

- Main Line Pipe: Delivers water from the river intake or pump station to the reticulation sub-mains and control head, in most cases these are manufactured from UPVC.

- Monitoring and Control: The Monitoring and control of a sprinkler system can be carried out manually or it may be automated with programmable controllers, pressure gauges and flow meters.

- Filtration unit: Filtration of micro and under canopy sprinkler systems is very important as the systems are susceptible to clogging from suspended inorganic particles (sand/silt) and from organic materials (algae) which may grow within the system. If a system becomes blocked, its performance is seriously affected.

- Pumping Station (or gravity intake if the terrain permits): to abstract water from the water source, deliver it into the distribution pipework system and to the sprinkler nozzle at the required operating pressure to ensure equitable and uniform distribution.

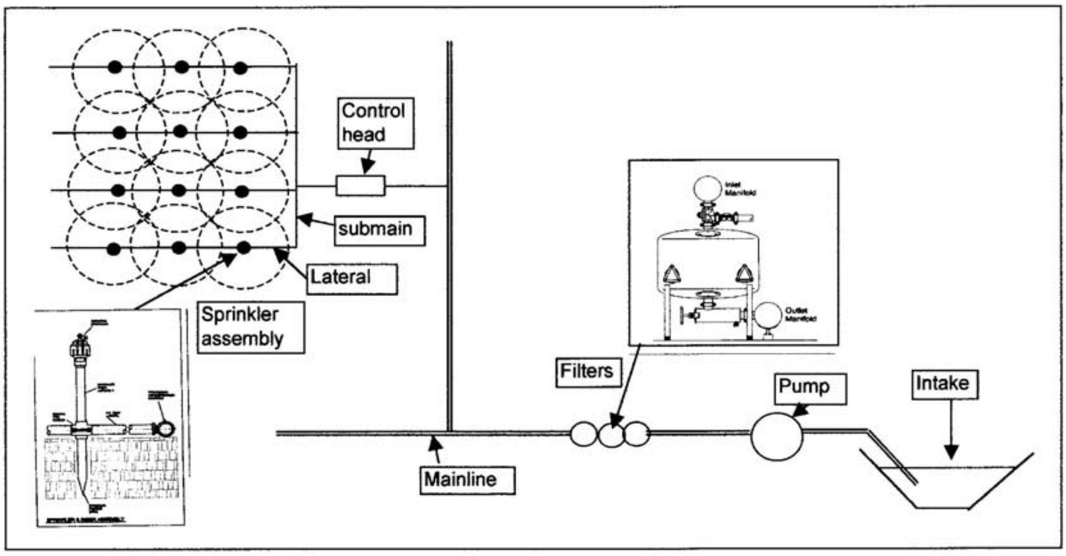


FIG 10: Main components of a typical sprinkler system

3.7.1.1 Design for Equipment Requirements

The sprinkler system should be properly designed hydraulically and economical in cost. The design of a sprinkler irrigation system involves the maximum rate of application, the irrigation period and the depth of application. The depth of application and the irrigation period are closely related. Irrigation period is the time required to cover an area with one application of water. The depth of application will depend on the available moisture-holding capacity of the soil.

3.7.1.2 Capacity of the Sprinkler System

The capacity of a sprinkler system depends on the area being irrigated, depth of water application at each irrigation, efficiency of application, and actual operating time for each irrigation. A sample sprinkler system design sheet based on the irrigation of 50 acres (20 ha) of open field Banana (high water requirement) production at Milton project site is presented in table 9.

Table 9: Sprinkler Irrigation Design Sheet

Based on Peak Crop Water Requirements		
Milton - Dominica	Assume No Rain	
Area of Scheme	20	Ha
Potential Eto (Melville Hall [1])	5.6	mm/day
DESIGN PARAMETERS		
Efficiency %	80	
Effective rooting depth of crop	0.7	m
Field capacity of soil	110	mm/m
field capacity within rooting zone	77.00	mm
Amount held at wilting point	20.00	%
moisture available for the plant	61.60	mm
Moisture retained in the soil	67.00	%
Net amount to apply with retention	20.33	mm
Maximum irrigation interval	3.63	days
Gross amount to apply at maximum interval	25.41	mm
Equivalent to a gross application per day	7.00	mm/day
SYSTEM DESIGN		
Irrigation cycle used	2.00	day
Gross application rate	14.00	mm
Total time of irrigation per day	9.00	
Total hours per set	4.50	hours
maximum number of sets per day	2.00	sets/day
precipitation rate of	3.11	mm/hour
area irrigated per set	5.00	ha
Spacing between laterals of	12	m
sprinkler spacing on the lateral	10	m
Theoretical sprinkler flow	0.1	l/s
and a precipitation rate of	3.11	mm/hr
selected sprinkler rate of	0.1	l/s
will give an actual precipitation rate of	2.88	mm/hr
and an actual operating time per set of	4.86	hr
This will still give a number of sets per day as	2	
with a total number of sprinkler positions of	1667	
the total number used per day will be	833	
with the number used per set of	417	
This will give an irrigated area per set of	5	
an area irrigated per day of	10	
and the area irrigated per irrigation cycle of	20	
The Flow rate per set is	40	l/s
	144	m3/hr
Total application per day	1399.68	m3
rate per hectare	2	l/s/ha

3.7.2 Drip Irrigation

Drip irrigation is increasing in popularity as the system of choice for many crops. Applying small amounts of water slowly and frequently through emitters spaced along polyethylene tape or tubing, potentially offers improved yields, more accurate and efficient irrigation, automation, as well as reduced fertilizer and chemical inputs. Drip irrigation are also used in conditions considered unsuitable for other irrigation methods, such as on, steep and undulating land or where water resources are restricted. The characteristics of this type of system makes it the most popular form for irrigating under shade/protected structures.

3.7.2.1 System components

Trickle system layouts are similar to sprinkler systems. The primary components for a trickle system include:

- A pressurised water supply, usually from a pump or gravity intake structure.
- An efficient filter
- Mains and sub-mains, usually buried PVC
- Control head consisting of pressure regulator, filter, control valve and often a tank for introducing nutrients (Fertigation) (see figure 11)
- A manifold pipe to which the laterals are connected (see figure 12)
- Lateral lines to which the emitters are attached. Laterals are usually flexible PVC or PE tubing, ranging from 10 to 32mm in diameter and have emitters spaced at short intervals appropriate for the crop to be grown.

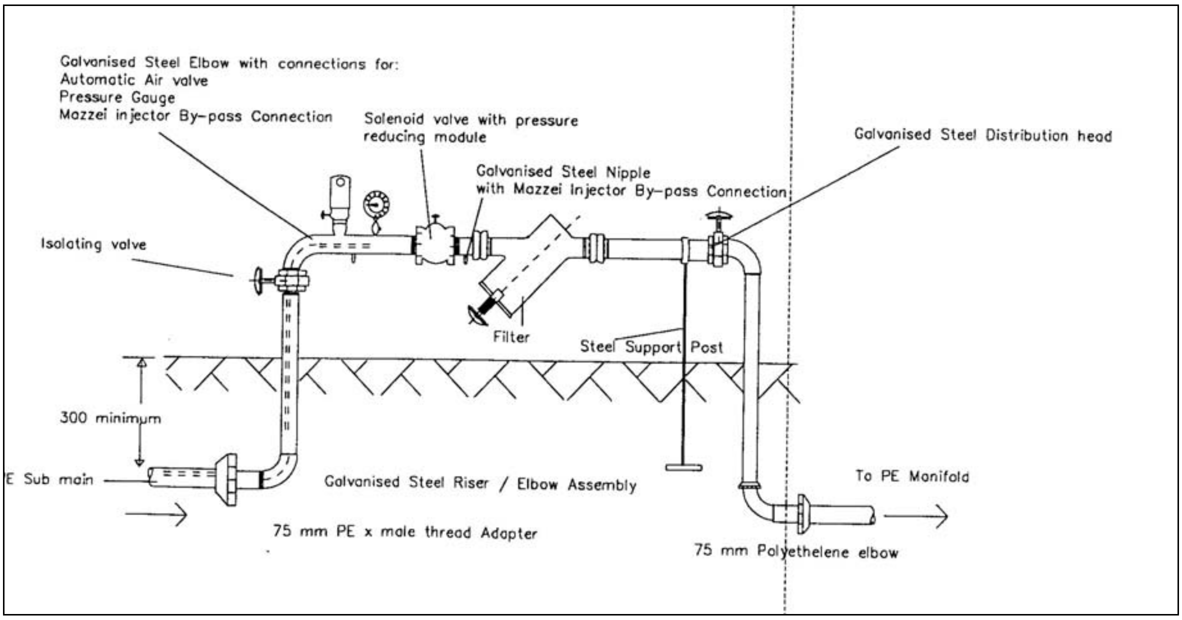


FIG 11: Typical Control Head arrangement

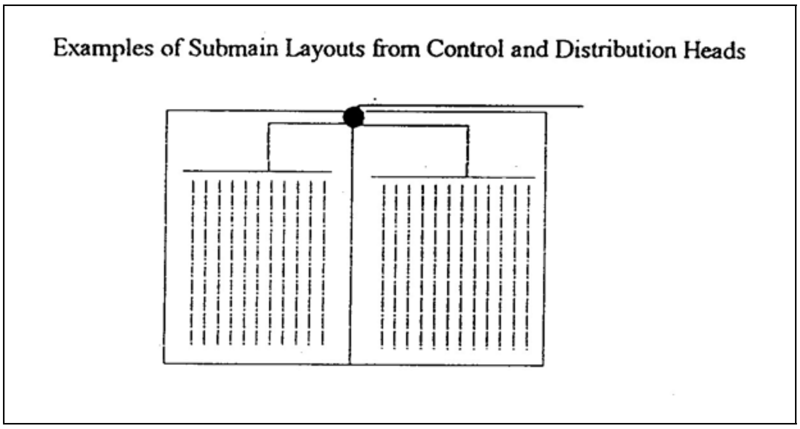


FIG 12: Sub-main and lateral layouts from Control Head

3.7.2.2 Emitters

Drip and trickle irrigation aim to deliver water to the plant root zone at a low flow rate but at frequent intervals. Many types and designs of emitters are available. The emitter controls the flow from the lateral by dissipating the pressure and allowing water to drip or ooze out close to the plant root zone. Small openings, long passageways, vortex chambers, manual adjustment or other mechanical devices accomplish the pressure dissipation. Some emitters may be pressure regulating to give nearly constant discharge over a wide range of pressures.

The soil moisture pattern with Trickle irrigation is shown in figure 13.

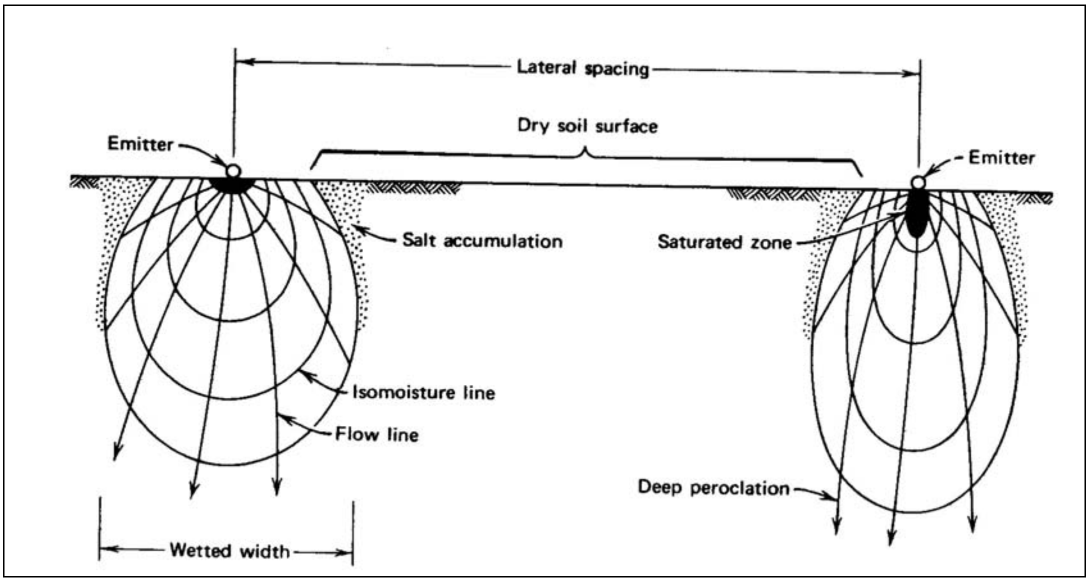


FIG 13: Soil moisture pattern with trickle irrigation

3.7.2.3 Advantages of Trickle Irrigation

The main advantages of a trickle irrigation system include:

- With trickle irrigation only the root zone of the plant is supplied with water and deep percolation losses are minimal.
- Soil evaporation is lower because only a portion of the surface area is wet
- Labour requirements are low and the systems can be readily automated
- Reduced percolation and evaporation losses resulting in greater economy of water usage
- Weeds are more easily controlled.
- Bacteria, fungi and other pests and diseases that depend on a moist environment are reduced.
- Low rates of water application at lower pressures are possible so as to eliminate runoff

3.7.2.4 Disadvantages of Trickle irrigation

The main disadvantages include:

- High initial cost and clogging of the emitters.
- Salt tends to accumulate along the fringes of the wetted surface strip
- Since trickle only wet part of the potential soil-root volume, plant roots may be restricted to the soil volume near each emitter.

3.7.2.5 Trickle system design

Trickle systems is designed using the same general rules and procedures as for sprinkler systems. The primary differences are that the spacing of emitters is much less than that for sprinkler nozzles and that water must be filtered and treated to prevent clogging of the small emitter orifices.

The diameter of the lateral or of the manifold should be selected so that the difference in discharge between emitters operating simultaneously will not exceed 10 percent. This allowable variation is the same as for sprinkler irrigation laterals. To stay within this 10 percent variation in flow the head difference between emitters should not exceed 15 percent.

A sample Trickle irrigation design sheet based on the Milton Irrigation project is presented in table 10 below:

Table 10: Drip Irrigation Design Sheet

DRIP IRRIGATION DESIGN SHEET		
Based on Peak Crop Water Requirements		
Milton - Dominica		
Area of Scheme	20	Ha
Plant Spacing	2.4	m
Row Spacing	2.4	m
Area per plant	5.76	m^2
No of plants	34722	
Canopy factor	0.85	
Crop Coefficient	1.2	
Potential Eto (Melville Hall [1])	5.6	mm/day
Efficiency %	95	
Leaching Requirement	0	
Gross Crop Water Requirement per day	40.74	litres/plant
	7.07	mm/day
	70.74	m^3/ha
Root area	4.896	m^2
Emitter flow rate (l/h)	2.5	l/h
Wetted area of emitter	1	m^2
Calculated no of emitters/plant	4	
maximum hours/day	24	hrs
Hours of operation for daily requirement	4.07	hrs
Irrigation cycle used	1.00	day
Gross application rate	7.07	mm
Total hours per set	4.07	hours
maximum number of sets per day	3.00	
area irrigated per set	6.67	ha
DRIP IRRIGATION DESIGN SHEET		
Emitters/ha	6944	/ha
metres of lateral line/ha	4167	m
emitter spacing along lateral	0.6	m
Total length of lateral line	138888.9	m
Total number of emitters	231481.5	
Lateral length	110	m
lateral flow	0.127315	l/s
lateral diameter	13.6	mm
Friction loss	75.84	m/1000
Friction Factor (multiple outlet)	0.35	
Lateral friction loss	2.91984	
Minimum operating pressure	15	m
Control unit serving up to 4no 0.5ha plots		
Flowrate to control unit irrigating 2 plots at once	4.822531	l/s
gross water requirement assuming 12hrs/day	1.637427	l/s/ha

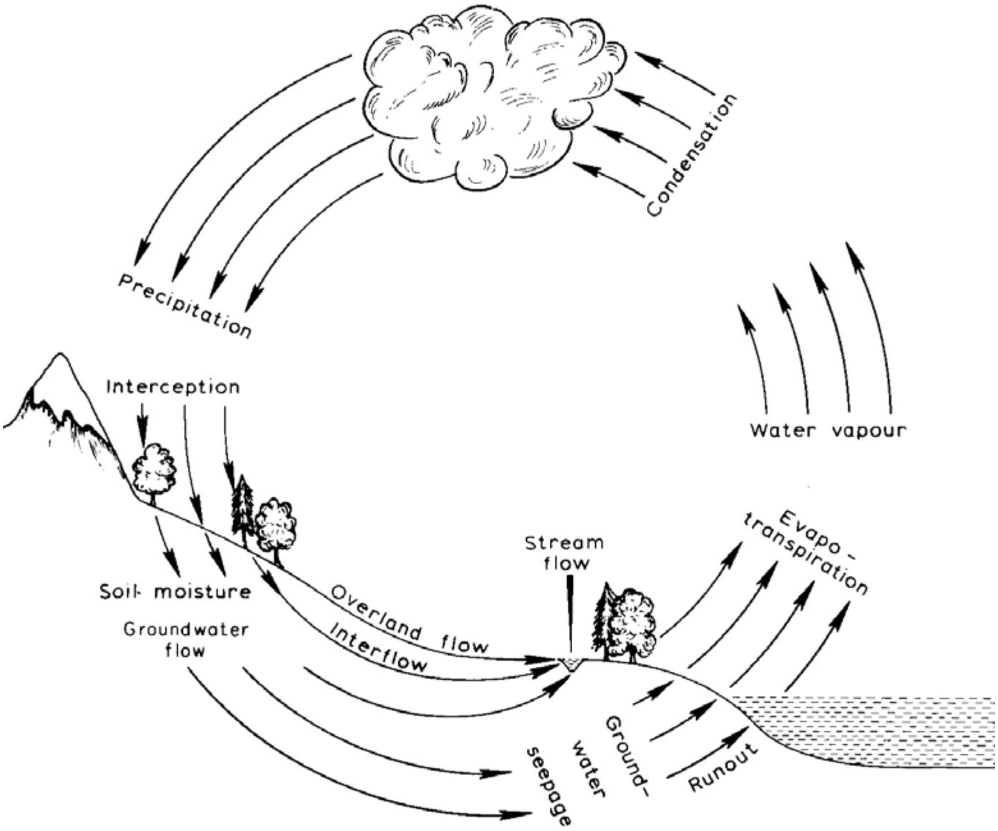
3.7.3 Gross Water Requirements for Milton Irrigation Scheme

From the two design sheets presented for Sprinkler and Trickle irrigation systems for the Milton area, to apply a gross irrigation application of 7mm per day, the proposed systems would need the following gross water requirements presented in table 11.

Table 11: Comparison of Gross Water Requirements

System	Application mm/day	No of sets per day	Area per set Ha	Area per day Ha	Total Hours per day	Flowrate l/s	Flowrate m^3/hr
Sprinkler	7.07	2	10	20	9.0	40	144
Trickle	7.07	3	6.67	20	12.2	32.7	117.7

The figures calculated here can now be used for the baseline design parameter of the hydrological report. The Hydrological Report will endeavour to determine the location of the intake structure that will give a reliable and sustainable yield in excess of the peak flow rates required to irrigate the whole of the Milton project area.



VOLUME 2

HYDROLOGY

MEASURES

Measures / Technical Nomenclature

d	:	day
ha	:	hectare
Kg	:	kilogramme
km	:	kilometre
kV	:	kilo Volt
kW	:	Kilo Watt
lpcd	:	litres per capita per day
l/s	:	litres per second
mm	:	millimetre
mm/d	:	millimetre per day
m^3/d	:	cubic metres per day
m^3/h	:	cubic metres per hour
mg/l	:	milligram per litre
Mm^3	:	million cubic metres
DN	:	Diameter Nominal in mm
H	:	hours
L	:	Length
lpcd	:	litre pre capita and day
M	:	Meter(s)
m^3	:	Cubic meter
masl	:	meters above sea level
Max.	:	Maximum
Min.	:	Minimum
Nos.	:	Numbers
Q max	:	Maximum Flow
V	:	Volume in m^3

4. HYDROLOGY

4.1 Scope and Objectives of the Project

Volume 1 of this report addresses the Crop Water Requirements for the Project area. These requirements become the starting point for Volume 2, which will analyse the available meteorological and hydrological data to assess the reliability and sustainability of the proposed location of the source for supplying the Milton Irrigation scheme.

The main scope of the Hydrological study is:

- Ascertain sufficient data to calculate the maximum and minimum flow achievable at a given intake location in order for the minimum water requirement to be supplied
- Construct intake to withstand a maximum flow scenario without major damage.
- The final supply chosen should meet the design criteria for the irrigation scheme on a sustainable basis.

The main criteria assessed include:

- Minimum flow rate supplied during a 1 in 5 year drought
- Maximum flow rate for a 1 in 50 year flood as per general industry standard

4.2 Water requirement to be supplied

Table 11 of Volume 1 infers that the required water supply flow rate, assuming that 100% of the command area was completed in one day, is 32.7 l/s for the trickle irrigation system operating for approximately 12 hours per day, and 40 l/s for the under canopy sprinkler system operating for a total of 9 hours per day.

4.3 The proposed intake position

The main agricultural production area of the Milton scheme is located on the main ridge below the syndicate settlement. To ensure the successful implementation of the proposed irrigation scheme, the following must be considered when situating the intake structure:

- The intake must be positioned at an altitude higher than the command area to ensure that adequate head is available to convey the water to the area and operate the chosen form of irrigation system.
- The Catchment area upstream of the Intake position must have sufficient “yield” to ensure that the intake can supply the required flow rate to the irrigation area without adversely affecting bio-diversity and other users.

A review of available water sources within close proximity to the project area identified a tributary of the Dublanc River to be the best possible water source.

There is a small, farmer managed irrigation system already existing on the chosen tributary. Mr. Richmond Shillingford established the system for the irrigation of a 3 hectare farm. He utilizes a combination of drip and micro sprinklers and extracts an estimated 6.5 l/s (max).

The chosen tributary also feeds the main Dublanc River, which is currently the source of DOWASCO's portable water supply to Dublanc and Bioche. An estimated six (6) l/s is required (12 hr day) to meet the water demand of 107.65 m^3/day at the storage tanks for Dublanc and Bioche. This water source is scheduled to be taken off-line on completion of the West Coast water project, which has already commenced.

4.3.1 Head available from proposed intake structure location.

Initial intake location investigation occurred in December 2010 mapping (1:25,000 Ordnance Survey Sheet, Edition 4-D.O.S. 1978), with ground truthing of certain points with an altimeter.

Actual survey of the alignment occurred during January 2011 by the Consultant team, using a theodolite and ranging staff. The profile is displayed on Fig 14 below. The survey indicated that, the head difference between the riverbed level at the Intake location (530.00m) and the delivery point on the top of the Ridge (365.7m) is 164.3m.

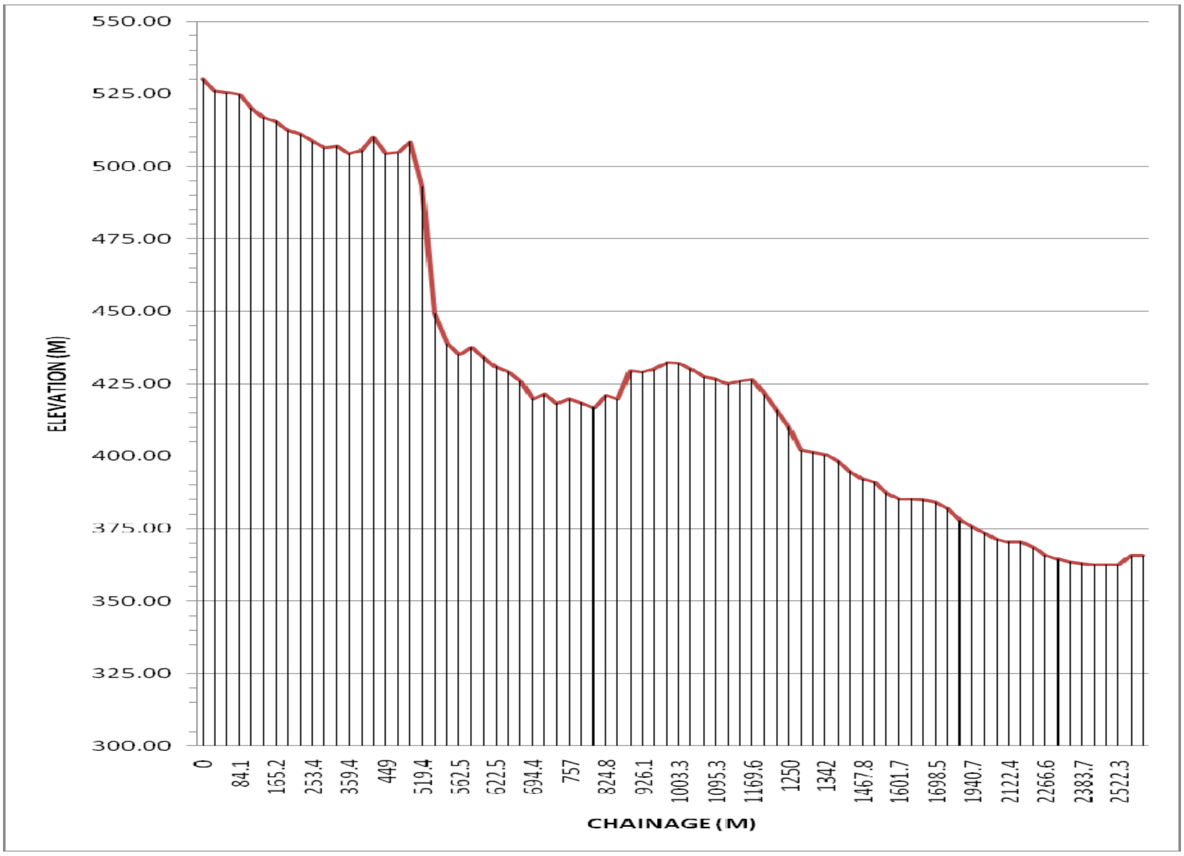


FIG 14: Supply pipeline longitudinal profile

4.4 Hydraulic Profile.

Hydraulic calculations for the main conveyance supply pipe along route surveyed in January 2011 was carried out using Hazen Williams's equation for friction loss in pipe flow.

Hazen Williams $Hf = 0.628LD^{-4.865}[100Q/C]^{1.852}$

Where: Hf = Head loss due to friction

L = Length of pipe in m

D = pipe Diameter in mm

Q = flow rate in litres/hour

C = Dimensionless coefficient of Friction (140 DI, 145 PVC and 150 PE)

The calculation of the hydraulic profile is based on a high density poly-ethylene H.D.P.E main from the intake to the irrigation project area. Head losses along the pipeline were calculated to verify the acceptability of the route and the intake location. The Hazen Williams coefficient for HDPE, 125 mm & 110 mm diameter, was used, as most of the alignment is foreseen to be exposed on slopes and also supported on the river banks and ravine crossings. Figure 15 shows the long profile and hydraulic gradient

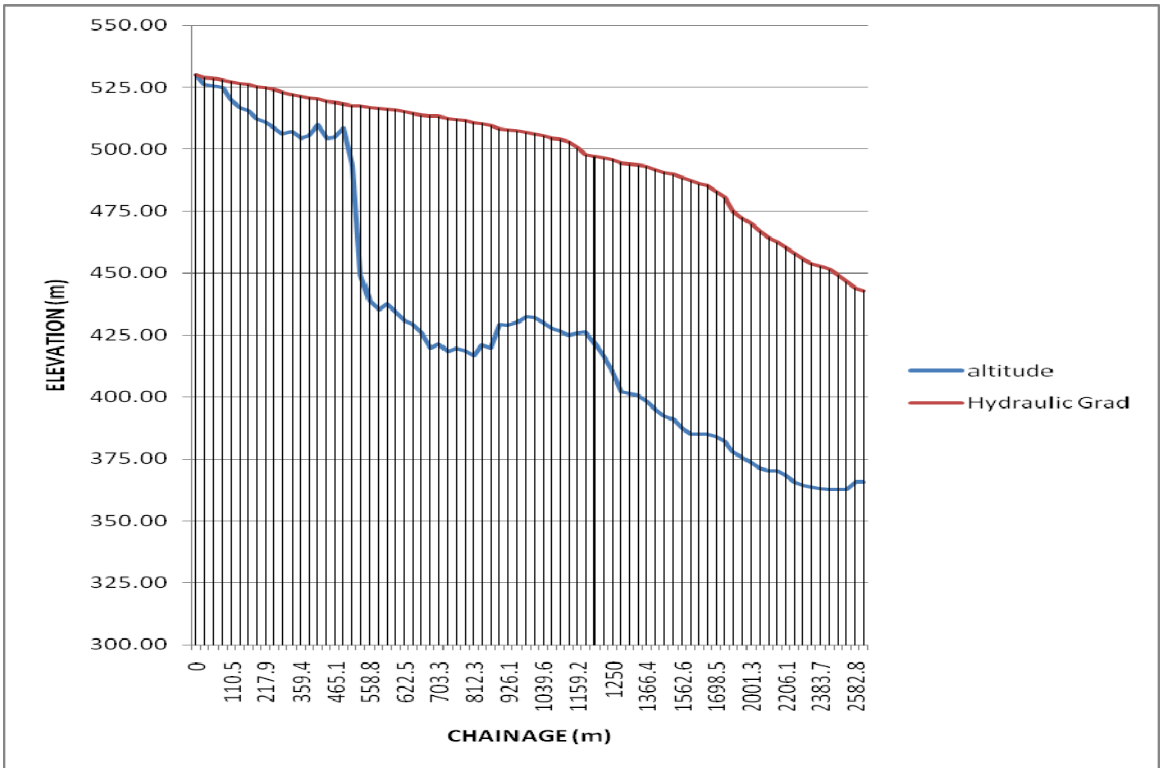


FIG 15: Hydraulic profile for the gravity main

Total friction headless along the 2605 m supply pipeline under flow conditions of 33 l/s is estimated at 87 m.

4.4.1 Pressure required to operate the proposed Irrigation system

As mentioned above, the intake must be positioned such that adequate head is available to convey the water from the intake to the irrigation area, with sufficient residual pressure to operate the irrigation system, including filtration units, distribution networks, sprinkler heads/trickle emitters and other main components indicated in Figures 11- 13 of volume 1. In order for the total head required to be calculated, the following parameters must be considered:

- Operating pressure at the field application level – at the sprinkler head or trickle lateral emitter level.
- Field distribution pipeline friction head losses from the control shed to the laterals
- Losses within the control shed – through the screen filter, flow meter and solenoid valve
- Losses along the main supply pipeline within the irrigation area.
- Losses at the main filtration system

The designed system should allow the entire command area to be irrigated by gravity, thereby reducing the expensive operating costs for pumping. The main advantage of the physical topography of the Milton area, is that it allows for increase in head as it moves towards the distribution area.
Detailed hydraulic analysis of the main distribution network was undertaken. Pipe sizes were selected such that pressure losses were managed, but in many cases, the pressure built up so quickly along the falling pipes that pressure regulators became necessary at certain locations.

All hydraulic calculations for the supply and distribution network are presented in Annex 2. The main criteria for sizing the pipe sections were to ensure that a minimum operating pressure of 30m was provided at the point of use. This was based on the assumption that the field application system foreseen requires a minimum operating pressure of 20m or 2 bar - Allowing for a loss of 10 m through the control shed installation. The flow rates required at each Control shed were also calculated based on the Trickle irrigation design sheet flow of 1.637 l/s/ha.

The system layout, based on the use of conventional sand and screen filters, control sheds and trickle irrigation equipment is indicated schematically in Annex 3.

5. ESTIMATING UPPER CATCHMENT CHARACTERISTICS

5.1 Data available;

As previously mentioned the main criteria assessed as part of the Hydrological study are:

- Minimum flow rate supplied during a 1 in 5 year drought
- Maximum flow rate for a 1 in 30 year flood

In order to calculate the above parameters, the following data was procured and analysed:

- Rainfall data for Melville Hall airport from 1969 to 2009
- Topographic survey sheets of the catchments
- Visual inspection and reconnaissance surveys of the catchment
- Data search of reports for flow measurement data.
- Isohyetal map of annual rainfall distribution in Dominica.
- Standard yield and runoff references and standard methods of calculation.

The above data was then used to obtain the following parameters:

- Monthly rainfall data analysis – 1 in 5 year drought
- Extrapolate the Melville hall data for the irrigated area and the Catchment area
- Assessment of the Characteristics of the Catchment and yield calculations
- Assessment of rainfall intensity and storm flows.

5.1.1 Rainfall data

The rainfall records from Melville Hall meteorological station between 1969 and 2009 (table 12) were analysed for the purposes of assessing the monthly average and the monthly 20 percentile (representing the values for a 1 in 5-year drought). This was selected as the closest representative rainfall gauging station with the longest period of records.

The monthly average and 1 in 5 year drought figures were then analysed further in an attempt to extrapolate the data for the Melville hall airport location, to create data applicable to the Milton irrigation and the upper catchment of the Dublanc River, where the intake structure will be located.

Table 12: Melville Hall Monthly Rainfall data (1969-2009)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1968										139.95	109.98	343.92	
1969	114.05	131.57	79.25	145.80	334.26	361.19	233.43	228.60	339.85	476.25	582.17	279.40	**3305.81**
1970	67.31	60.45	67.82	67.56	215.14	326.64	406.40	320.29	369.32	536.70	430.28	484.63	**3352.55**
1971	96.52	85.34	42.16	49.78	137.67	117.09	176.53	254.76	116.33	178.82	64.26	255.02	**1574.29**
1972	169.42	183.39	256.54	259.08	155.45	220.22	104.65	403.61	359.41	320.29	266.19	224.79	**2923.03**
1973	120.40	91.69	106.17	93.47	36.58	227.33	143.76	309.37	371.86	179.58	156.21	116.84	**1953.26**
1974	245.62	148.59	187.20	67.56	163.58	172.21	72.39	128.02	468.38	322.33	226.57	161.29	**2363.72**
1975	113.54	93.22	161.54	43.69	89.41	93.47	59.69	163.32	139.19	470.15	337.06	506.73	**2271.01**
1976	214.12	163.58	80.77	82.04	184.91	159.00	135.38	158.24	273.05	532.89	277.37	560.83	**2822.19**
1977	61.98	28.45	72.14	131.06	116.84	71.63	136.14	284.73	328.42	452.88	439.42	110.24	**2233.93**
1978	284.73	29.72	109.98	192.53	204.47	116.84	175.51	232.66	251.97	338.84	184.66	101.60	**2223.52**
1979	59.69	113.28	218.19	30.48	205.49	439.67	234.70	378.21	499.36	469.65	651.26	227.58	**3527.55**
1980	63.75	133.60	51.82	120.65	86.61	185.67	208.28	284.23	241.81	291.34	311.66	166.12	**2145.54**
1981	208.28	157.73	60.71	762.51	420.12	191.01	218.95	405.89	332.23	262.13	214.38	487.43	**3721.35**
1982	114.30	175.77	83.31	132.08	566.17	180.34	364.49	251.97	244.09	226.57	404.62	618.24	**3361.94**
1983	58.17	129.79	138.68	52.83	349.50	133.60	201.42	204.72	311.66	140.97	97.54	128.78	**1947.67**
1984	125.48	70.36	198.37	96.01	78.49	158.50	228.85	81.79	330.20	366.01	693.93	161.80	**2589.78**
1985	98.30	67.06	153.67	97.79	91.44	59.18	187.96	177.80	272.29	508.00	472.69	111.51	**2297.68**
1986	200.66	32.51	170.94	223.01	251.97	141.22	144.53	234.19	263.14	243.59	699.01	197.10	**2801.87**
1987	92.46	51.31	66.80	29.97	815.59	424.18	158.24	236.47	120.40	389.13	721.87	140.72	**3247.14**
1988	135.38	98.30	173.23	152.91	197.61	246.89	273.30	442.47	370.08	344.42	316.23	140.21	**2891.03**
1989	68.58	196.60	260.60	130.05	55.12	43.18	273.30	411.23	545.34	277.11	148.34	163.83	**2573.27**
1990	97.79	122.17	102.36	296.93	191.77	121.41	151.38	205.49	210.31	360.68	291.85	213.11	**2365.25**
1991	69.09	103.12	84.33	116.84	63.25	247.90	172.97	180.09	247.40	93.98	490.73	192.28	**2061.97**
1992	147.83	77.22	50.80	153.92	239.27	247.90	247.40	315.47	345.44	141.73	283.46	189.48	**2439.92**
1993	155.96	170.18	109.22	143.76	541.53	174.50	210.82	259.59	465.07	239.52	375.41	207.01	**3052.57**
1994	80.01	89.41	27.69	49.28	194.31	88.90	57.40	181.36	370.84	269.24	246.38	295.40	**1950.21**
1995	217.17	106.93	295.91	177.55	68.33	58.67	294.64	406.91	551.94	240.79	201.42	218.44	**2838.70**
1996	126.75	76.96	173.74	113.28	114.81	149.35	328.42	170.69	568.96	372.62	279.15	279.15	**2753.87**
1997	179.58	86.11	123.70	18.80	277.37	129.29	338.07	208.03	243.84	309.37	150.11	130.56	**2194.81**
1998	248.92	33.27	65.28	227.84	292.10	254.00	305.56	256.79	260.86	644.91	356.62	372.62	**3318.76**
1999	204.72	103.12	168.40	215.90	75.95	215.39	232.16	140.46	184.91	351.28			
2000	213.60	90.10	98.60	76.60	139.00	106.00	189.90	236.60	241.20	273.40	460.40	122.40	**2247.80**
2001	82.70	97.10	50.30	75.00	12.10	129.20	314.80	257.20	134.70	522.00	109.30	631.40	**2415.80**
2002	95.70	118.80	104.20	467.10	339.10	115.00	210.40	168.60	167.30	225.60	254.30	99.80	**2365.90**
2003	83.00	57.20	35.10	174.90	139.20	346.50	309.60	328.70	146.90	347.30	526.70	223.90	**2719.00**
2004	148.70	106.40	141.70	76.40	627.70	117.10	269.20	231.40	744.50	182.70	912.00	174.00	**3731.80**
2005	168.40	196.50	31.20	60.90	208.30	369.30	231.80	229.00	150.40	352.50	320.30	99.10	**2417.70**
2006	94.30	51.60	94.80	72.10	172.30	350.60	293.30	201.10	192.70	477.10	243.00	311.70	**2554.60**
2007	174.00	53.60	79.90	107.50	81.20	153.80	141.00	409.60	263.30	586.50	123.20	159.40	**2333.00**
2008	129.80	134.90	108.60	87.50	159.10	154.80	206.10	170.70	551.00	368.70	228.40	130.30	**2429.90**
2009	152.20	88.90	48.00	267.80	310.10	256.30	162.20						
Average	136.17	102.58	115.46	144.90	219.59	191.59	214.76	253.76	314.75	342.19	347.40	240.89	**2623.58**
%age	5.19	3.91	4.40	5.52	8.37	7.30	8.19	9.67	12.00	13.04	13.24	9.18	
Lowest	58.17	28.45	27.69	18.80	12.10	43.18	57.40	81.79	116.33	93.98	64.26	99.10	**1574.29**
20% ile	82.70	60.45	66.80	67.56	86.61	116.84	144.53	176.38	191.14	236.93	184.66	140.21	**1554.82**

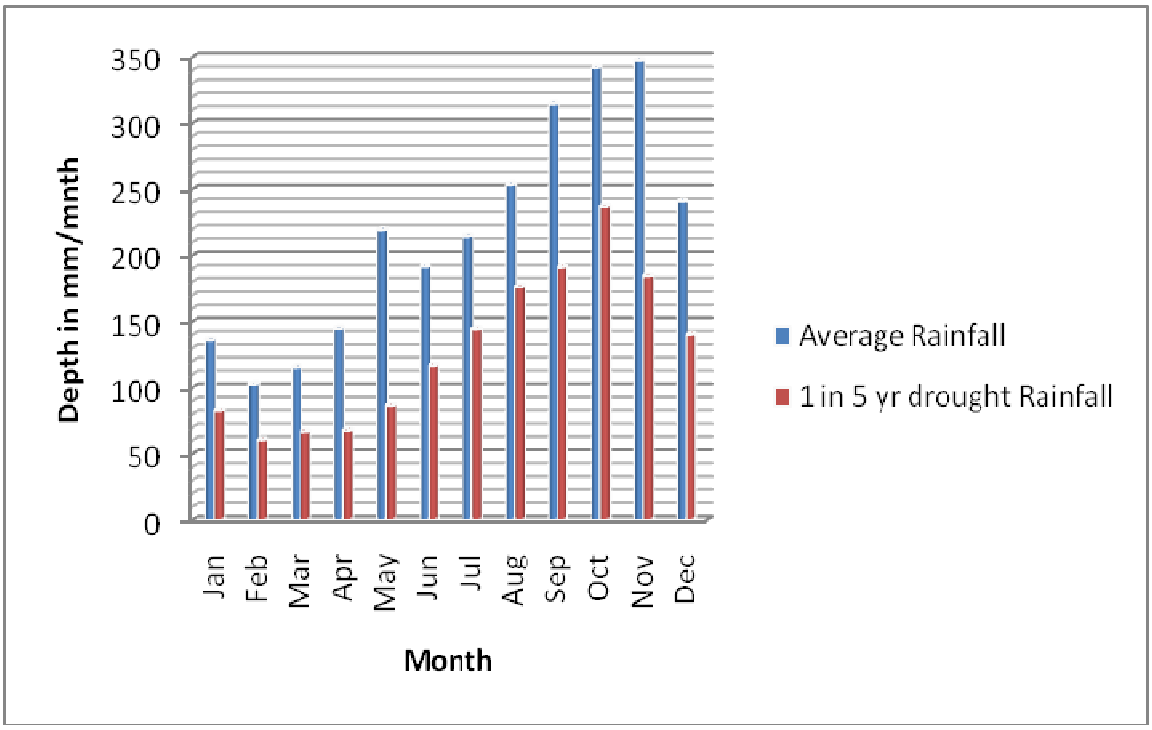


FIG 16: Average Monthly Rainfall for Melville Hall (1968-2009)

Figure 16 illustrates the distribution of annual average rainfall for Melville Hall, Dominica. The dry season extends from January through to June/July, followed by a much wetter season from August through to December. This corresponds to the heavy rainfall associated with the hurricane season

5.1.1.1 Analysis of Rainfall data

The daily rainfall data from the rain gauge at Melville Hall represents the rainfall distribution and depth for the low-lying East coastal fringe. The annual rainfall increases notably further inland, corresponding very closely with the change in altitude. The highest annual rainfall occurs on the summits of the two main volcanic peaks of Morne Diablotin and Morne Trois Pitons (see Figure 17), where rainfall isohyets range from 100 inches (2540 mm) in the East coastal regions, up to 300 inches (7720mm) on the mountain peaks.

The catchment areas for the identified intake locations indicated on the Isohyets map fall in the annual rainfall zone of 250 inches or 6,350mm. The analysis assumed that the monthly distribution of rainfall would be very similar to that measured at Melville hall, even if the annual figures were higher. The average and 20 percentile values (1 in 5-year drought) were calculated for Melville hall and expressed as a percentage of the annual rainfall. These figures were then extrapolated to calculate the average and 1 in 5 year drought monthly rainfall totals for the upper catchment (table 13 & figure 17).

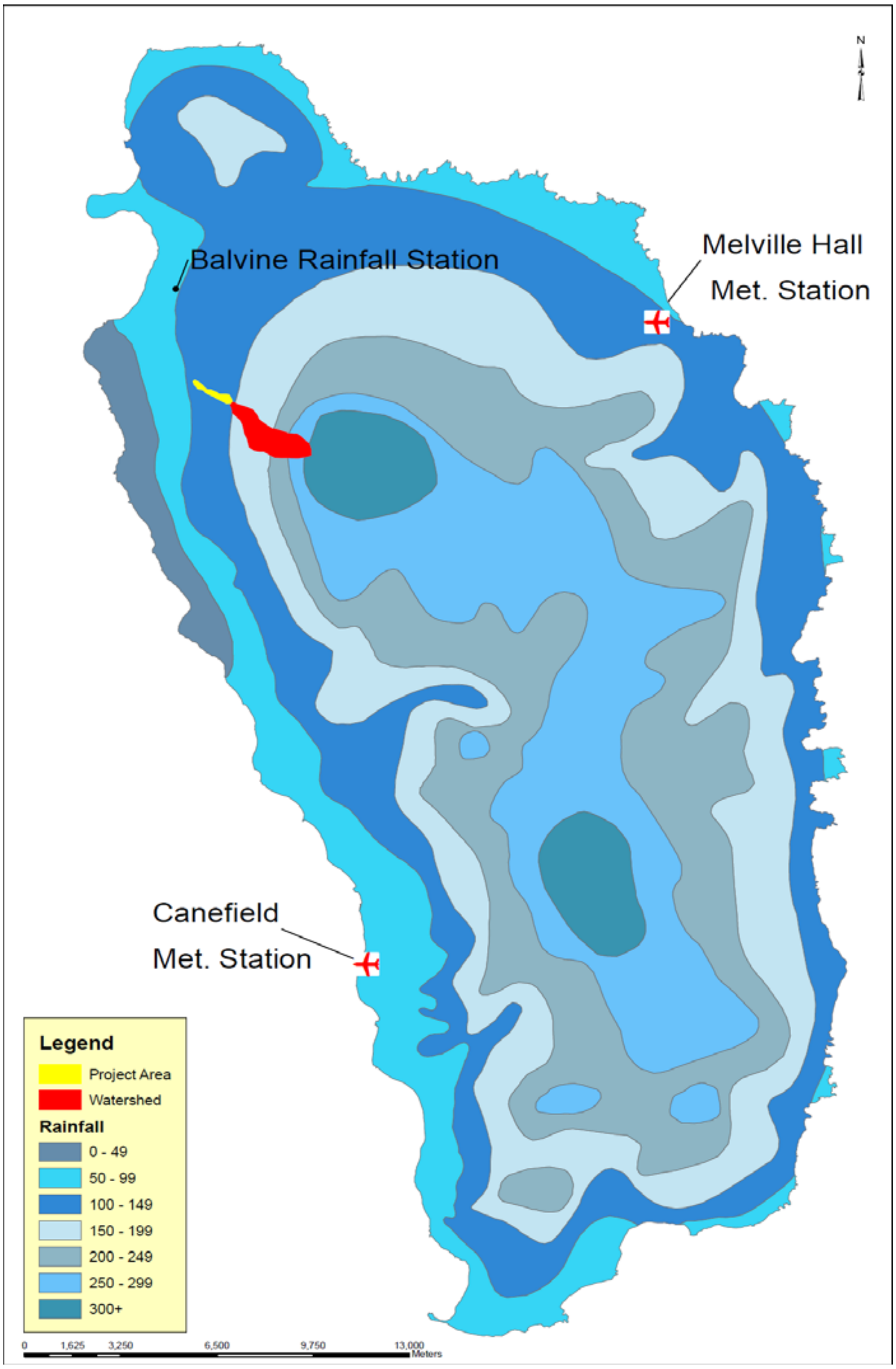


FIG 17: Precipitation Map of Annual Rainfall, Dominica

Table 13: Average and 1 in 5 year rainfall for the Milton catchment

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Average	329.58	248.29	279.45	350.70	531.48	463.70	519.79	614.19	761.80	828.22	840.82	583.04	**6350.00**
1 in 5	195.32	147.14	165.61	207.84	314.97	274.81	308.04	363.99	451.47	490.83	498.30	345.53	**3763.21**

1 in 5 year based on estimated average annual rainfall in the Milton River Upper catchment of 6,350mm

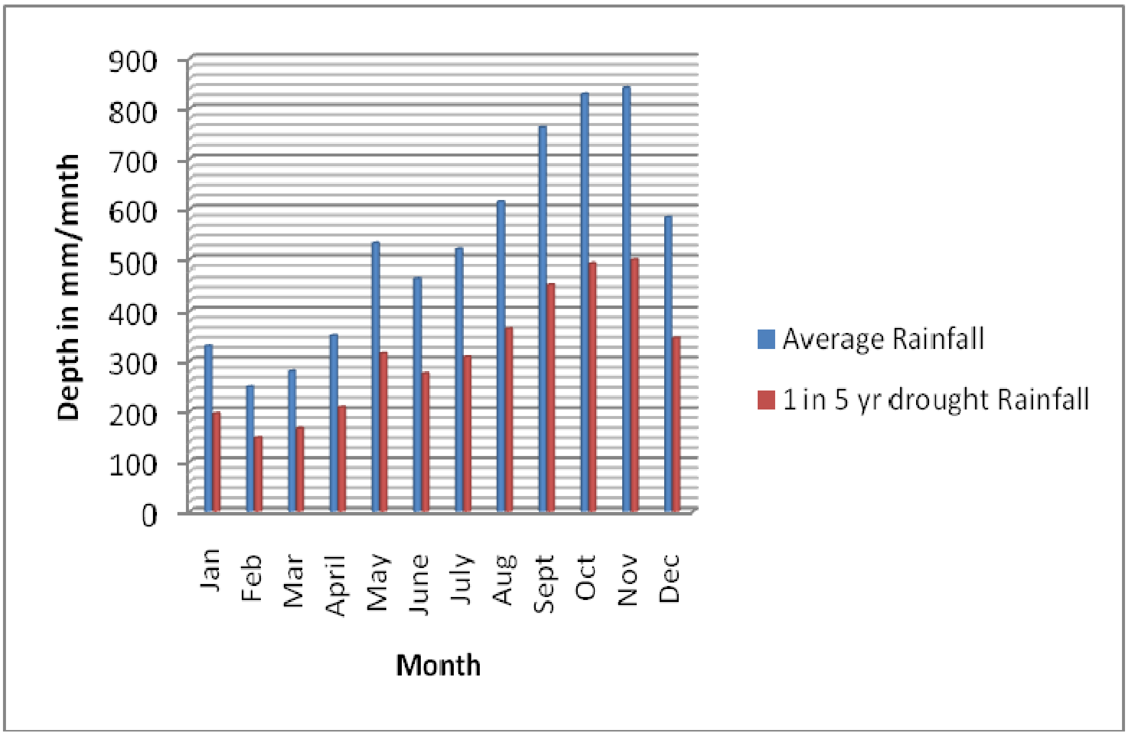


FIG 18: Average Monthly Rainfall for Milton River Catchment

5.2 Catchment Characteristics

The fate of rainfall in natural catchments includes:

1. Interception by vegetation
2. Infiltration into the soil,
3. Movement over the soil surface and becoming trapped in depressions
4. Evaporation into the atmosphere.

Estimates of run-off therefore depend upon two processes namely, an estimate of the rate of rainfall, and an estimate of how much rainfall becomes run-off.

The proportion of rain that becomes run-off depends on factors such as the topography, the vegetation, the infiltration rate, the soil storage capacity, the drainage pattern. These characteristics are critical in the determination of peak drainage flow and the design of structures to withstand floods of a certain magnitude and return period.

For catchment yield under low flow, dry year conditions, which is the main basis for the intake design for the Milton irrigation scheme, an estimation of the base river flow is required.

The catchment area for the intake option is indicated in Figures 19.

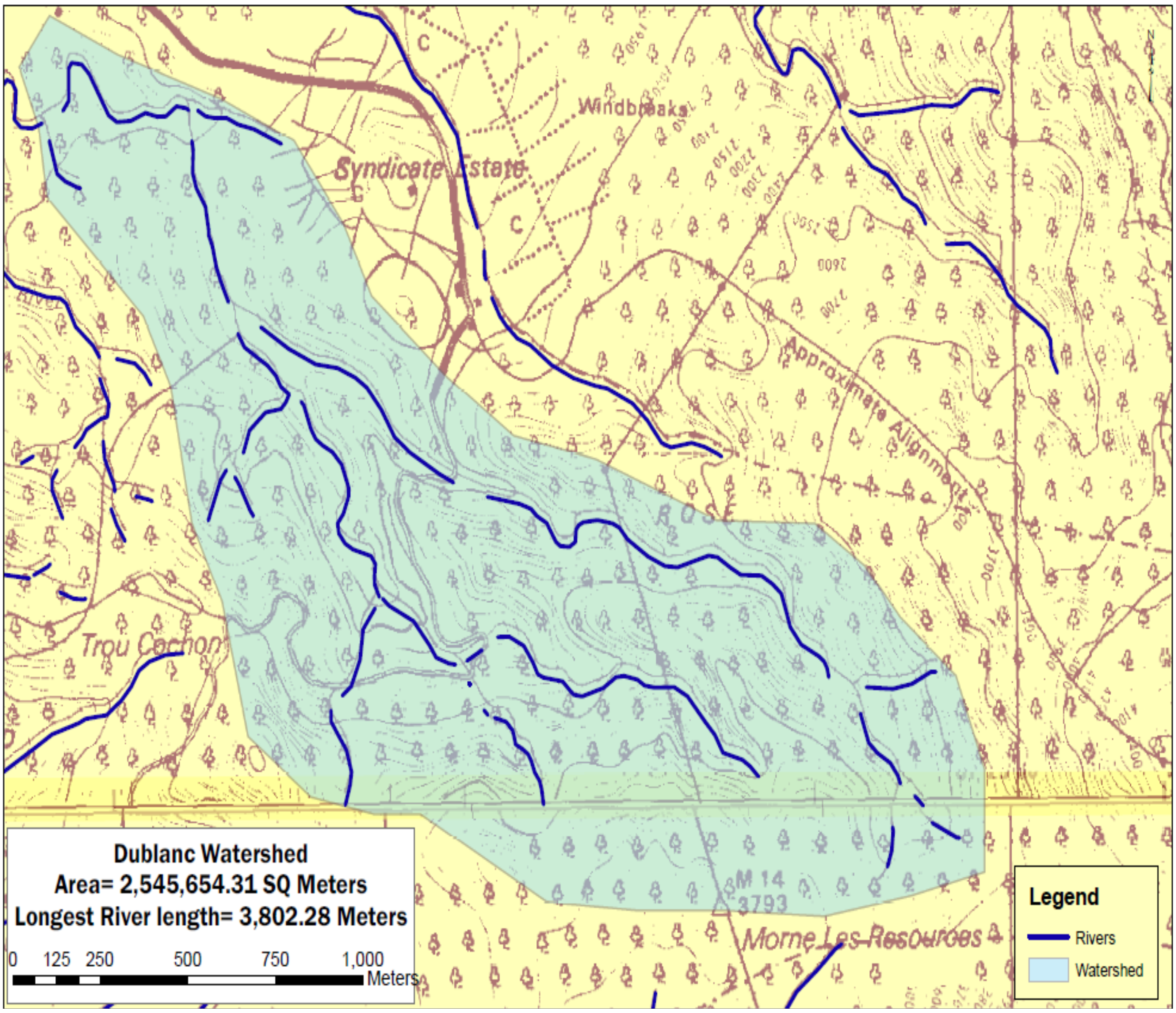


FIG 19: Main Catchment Area for Milton Irrigation Scheme

5.3 Estimation of Base-flow in Catchment

As earlier mentioned, minimal baseline data to include river gauging was available locally. DOWASCO monitors a few rivers that are critical for providing portable water. Results of literature search of available records upon which to base the analysis of base flow from the catchment revealed 4 spot measurements of relevance by DOWASCO. Additionally, in the report "Water Resources Assessment of Dominica, Antigua and Barbuda, and St. Kitts and Nevis" completed by The United States Southern Command: The US Army Corps of Engineers Mobile District and Topographic Engineering Centre, December 2004, three discharges were measured within the Melville Hall basin on 13th November 1997 (see table14).

One measurement was also completed during the initial source and intake cross-section survey in February 2011. This coincided with the end of an extended rainy season.

Table 14: Discharge measurements within the project area and Melville Hall

Date	Location	Discharge (m^3/s)
21-Feb-92	Above intake in Dublanc el. 340 ft amsl	0.071
13-Nov-97	Mouth of Melville Hall River	2.600
17-Feb-00	Above intake in Dublanc el. 340 ft amsl	0.346
5-Nov-04	Upper Syndicate River Crossing	0.083
19-Jun-08	Above intake in Dublanc el. 340 ft amsl	0.077
24-Jul-08	Above Intake in Dublanc el. 340 ft amsl	0.164

Analysis of the rivers, their catchments and the monthly rainfall figures, will give an estimate of monthly rainfall run-off and base flow. This was achieved by estimating the total catchment of the river and comparing the catchment area and characteristics to the discharges measured.

An assessment was made of the proportion of each of the catchment areas that were in the various rainfall isohyets areas to estimate their contribution to flow, (fig 20).

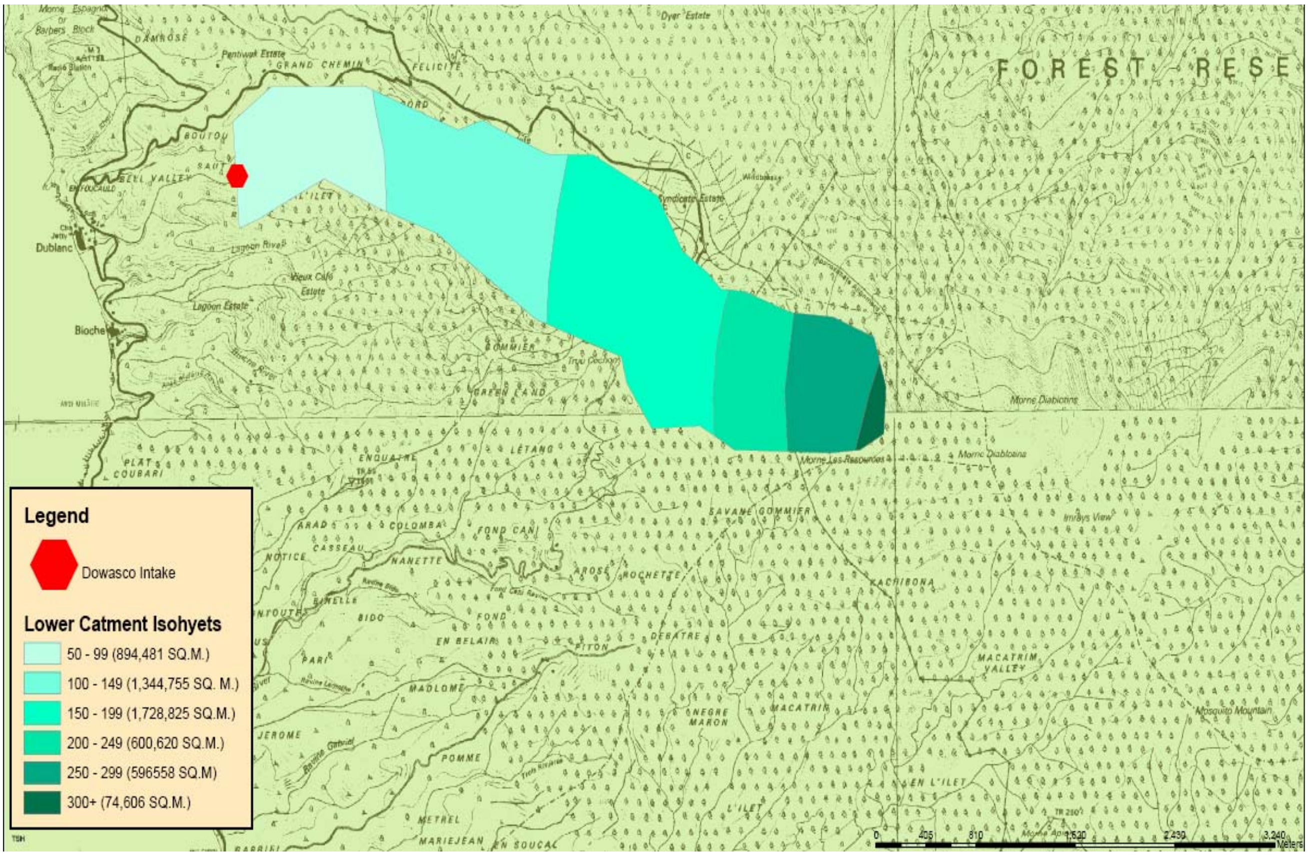


FIG 20: DOWASCO's Dublanc Intake Water Catchment with Isohyets

With the proportion of flows in the rivers expressed on a litre per second per hectare basis (l/s/ha), it was possible to estimate the proportion of flow that was attributable to the monthly rainfall and the proportion that was base flow from springs and groundwater seepage.

The catchment areas and flows for the Melville Hall, and the Dublanc River are listed in table 15.

Table 15: Discharge comparisons expressed per unit area of catchment

River	Area Ha	Discharge (m^3/s)	Average (l/s/ha)
Melville Hall -Mouth	3400	2.6 m^3/s	0.76
Dublanc – Dowasco Intake	594	0.071	0.120
-Do-	594	0.346	0.582
-Do-	594	0.077	0.130
-Do-	594	0.164	0.276
Dublanc - Milton Intake	255	0.093	0.36

The catchment area of the water intake for the proposed irrigation project makes up 43% of the total catchment area of the DOWASCO's water intake catchment. In fact, it can be considered to be with the upper catchment of the DOWASCO's water intake catchment. (See fig 21, highlights in table 15).

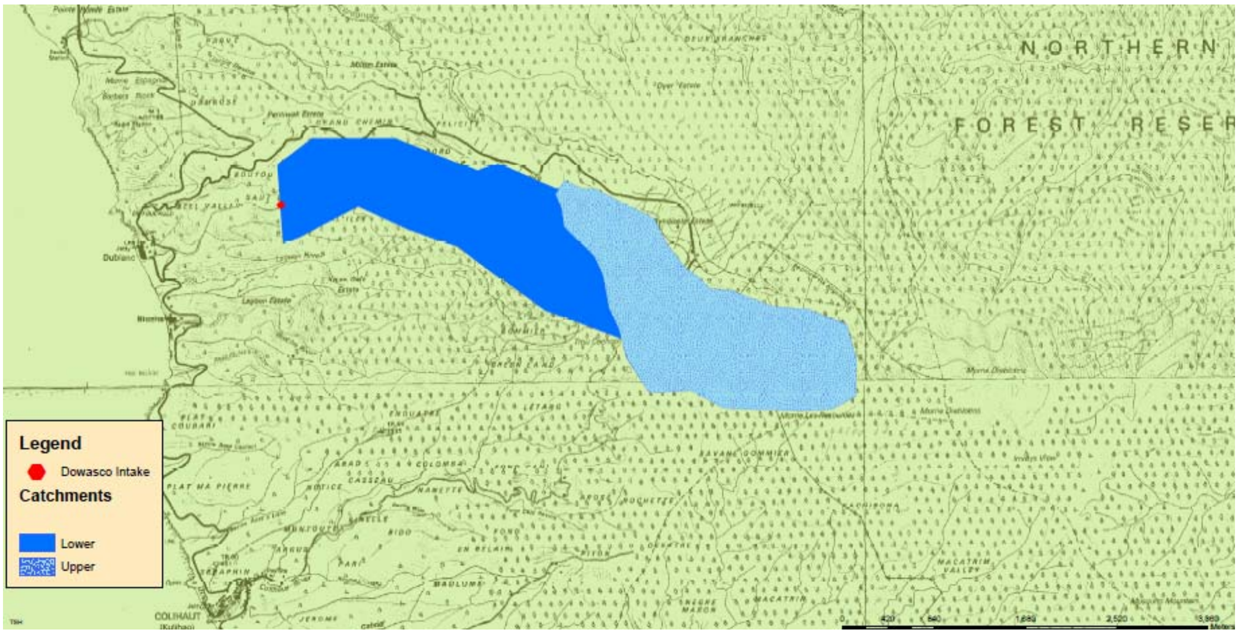


FIG 21: Catchment area for DOWASCO's Water Intake with catchment for proposed project

Based on the analysis presented in table 15, the base flow was calculated by deducting the flow attributable to rainfall from the calculated yield in Litres/second per hectare. The run-off coefficient of rainfall C was determined using table 16:

Table 16: Values of Run-off Coefficients

Topography and vegetation	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland			
Flat 0-5 % slope	0.10	0.30	0.40
Rolling 5-10% slope	0.25	0.35	0.50
Hilly 10-30 % Slope	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Steep	0.22	0.42	0.60
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Steep	0.52	0.72	0.82

From the table above, the category that best describes the upper catchment of the Dublanc River is Woodland with hilly topography on Clay and silt loams. A run-off coefficient of 0.5 was therefore assumed.

Based on the assumption that the monthly rainfall is equally distributed, and that the coefficient of run off C=0.5, the proportion of the total unit flow that is attributable to rainfall runoff can now be calculated. The remainder of the flow can thus be attributed to the baseflow component. The flow measurement at the proposed intake site was completed in February 2011. The average rainfall for the month of February (table 12) is 102.58 mm. Over 28 days is equivalent to 3.66 mm/day. Assume coefficient of C=0.5. The proportion contributing to runoff is 1.83 mm/day. This is the equivalent to 0.212 l/s/ha. Base flow for the two rivers are presented in table 17.

Table 17: Unit Base flow calculations for Catchment of proposed Intake

River	catchment (l/s/ha)	Rainfall (mm)	Coefficient C	Rainfall Component (l/s/ha)	Base flow (l/s/ha)
Melville Hall	0.92	363.33	0.5	0.70	0.22
Dublanc – Proposed Intake	0.37	102.58	0.5	0.212	0.158

Estimation of 1 in 5 year drought flows in Catchments

Based on the catchment areas calculated for the proposed intake structures, 255 ha, it is now possible to ascertain the reliability of supplying a sustainable flow rate to the Irrigation scheme, using the 1 in 5-year rainfall data extrapolated for the upper catchment area. The analysis is presented in the table 18 below,

Table 18: 1 in 5 year drought yield flows at the proposed Intake sites.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1 in 5	195.32	147.14	165.61	207.84	314.97	274.81	308.04	363.99	451.47	490.83	498.3	345.53
Equivalent l/s	0.729	0.608	0.618	0.802	1.176	1.060	1.150	1.359	1.742	1.833	1.922	1.290
0.5 Coeff	0.365	0.304	0.309	0.401	0.588	0.530	0.575	0.679	0.871	0.916	0.961	0.645
Baseflow l/s/ha	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158
Total l/s/ha	0.523	0.462	0.467	0.559	0.746	0.688	0.733	0.837	1.029	1.074	1.119	0.803
Catchment l/s	133.3	117.8	119.1	142.5	190.2	175.5	186.9	213.6	262.4	273.9	285.4	204.8

5.4 Estimation of 1 in 5 year drought flows in Catchments

The estimations and calculations of table 18, completed with the limited hydrological data available, can now be utilized to ascertain the suitability of the proposed intake structure sites.

An irrigation demand of 1.637 l/s/ha has already been established for the scheme with a total command area of 20 Ha. The required flow at the intake will therefore need to be equal or exceed 32.74 l/s for meeting the demand of the command area in one irrigation cycle.

The propose intake position is estimated to yield more than the maximum irrigation requirement even in the driest 1 in 5 year drought month (table 18) and so is acceptable. Further, even when combined with the extraction by the private irrigation scheme, it stays within the tolerance of 33% allowable extraction even for the driest month in the 1 in 5-drought event.

5.5 Estimation of flood runoff

5.5.1 The Rational Method

In the absence of available flood data, the most commonly used methodology for Peak Rate of Run-off is the Rational Method.

The main advantage of the Rational Method is that it can always be used to give an estimate of the maximum run-off rates no matter how little recorded data is available.
The Rational Formula:

$$Q = \frac{CIA}{360}$$

Where: Q is the peak flowrate in cubic metres per second
C is the dimensionless run-off coefficient
I is the intensity of rainfall in mm per hour
A is the area in Hectares

5.5.1.1 Time of concentration

The storm duration, which corresponds to the maximum rate of run-off, is referred to as the *Time of Concentration* or the *gathering time.* It is defined as the longest time taken for water to travel by overland surface flow from any point in the catchment to the outlet. Maximum runoff will therefore result when the whole catchment is yielding run-off at its maximum rate. Since the intensity/duration curves show that intensity decreases as duration increases, the maximum rate of rainfall, and therefore the maximum rate of runoff, will occur in a storm with the shortest duration, which will still allow the whole catchment to contribute run-off.

Kirpich Formula

$$T\ (minutes) = 0.02L^{0.77}S^{-0.385}$$

Where T is the time of concentration in Minutes
L is the maximum length of flow in metres
S is the average stream gradient in metres/metre

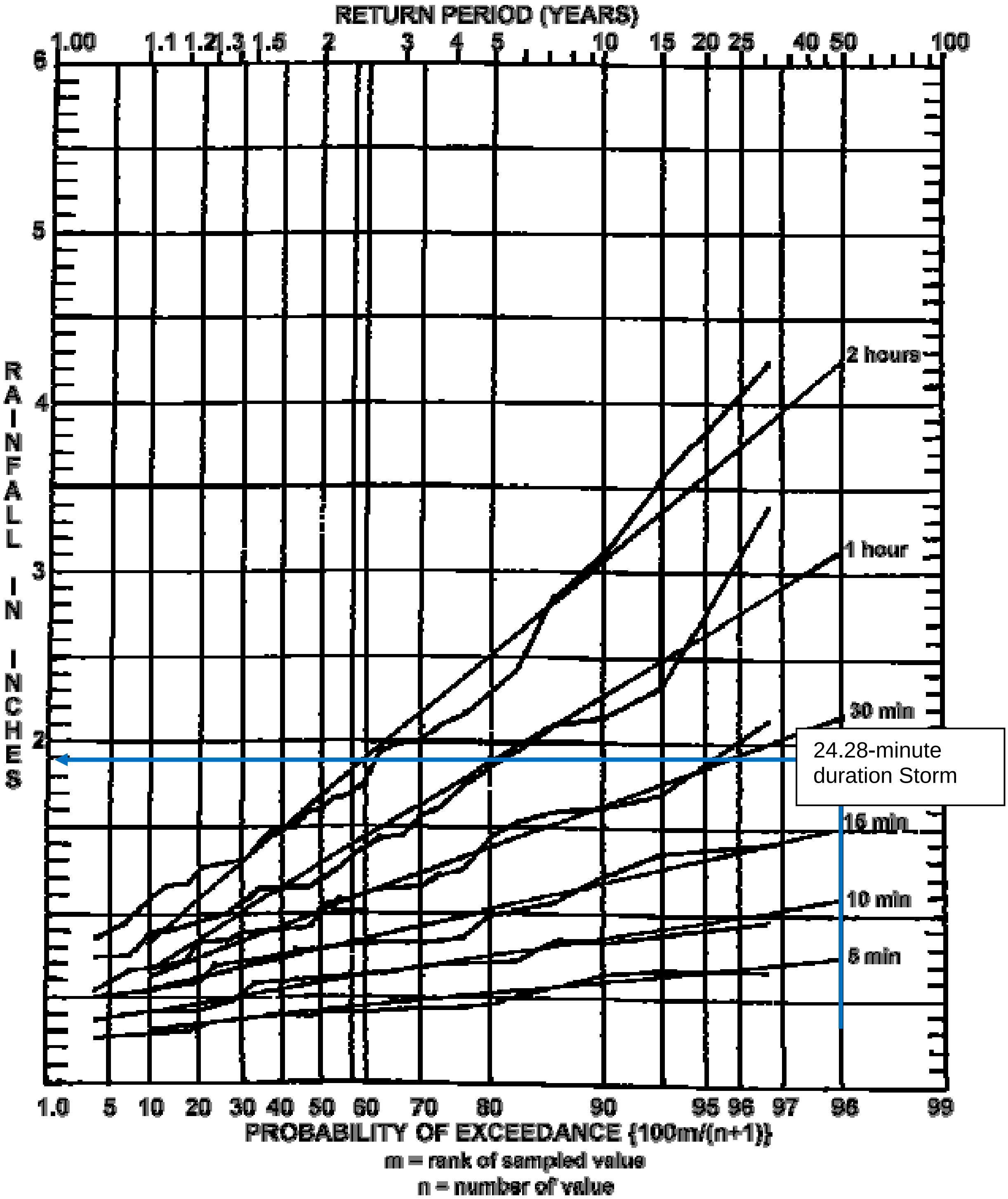
From the catchment area map, the following parameters were measured:

L = 3802 m

S = (1067-530)/3802 = 0.141

Therefore: T = 24.28 minutes

A Rainfall and duration curve taken from the "*Manual for Caribbean Electric Utilities addressing the issue of mitigation of damage caused by Natural Hazards to Civil Works"- USAID-OAS Caribbean Disaster Mitigation Project: Sept 1996*: was used to calculate the peak flow for a 1 in 50-year flow, fig 21B & 22:



For a 24.28 minute duration storm a 1 in 50 year storm = 1. 9 inches or 48.26 mm

1in 50 rainfall Intensity = 48.26/0.40 = 119.26 mm/hr

1 in 50 year flow for catchment Q = CIA/360;

Q= flow in cubic metres per second, I = 119.26mm/hr, A= 255 Ha, C= 0.5

Q= (0.5 x 119.26 x 255)/360 = 42.24 cu.m/s

FiG 21B: Rainfall return period and Storm flow calculation

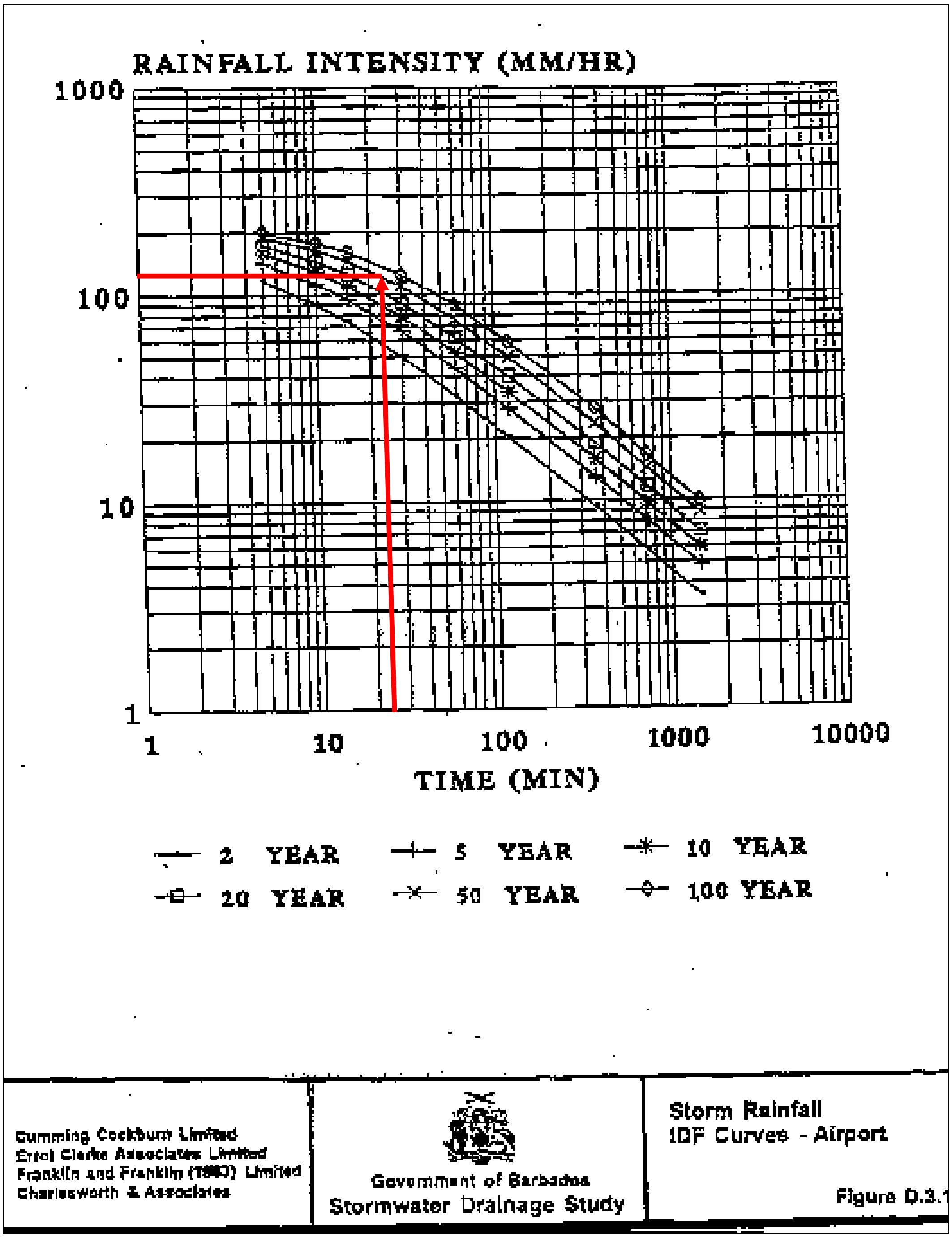


FIG 22: Rainfall Intensity based on 24.28 minutes of 1 in 50 year storm event

5.6 Design limits - 1 in 50 year Storm Flow

From the two charts above, the Intensity of the 1in 50 year event, based on a storm duration of 24.28 minutes, is approximately 119.26 mm/hour. The Calculation of the Peak flow in the Milton River at the proposed Intake structure during this storm event is therefore estimated using the Rational formula as 42.24 cu.m/s.

5.7 Depth of Flow at the intake for a 1 in 50 year Storm Flow

Taking a step method analysis of the measured cross-section of the river at the proposed intake location, the depth and velocity of the 1 in 50 year storm flow was calculated. The analysis is shown below:

Normal Depth Calculation (using mannings equation)
At intake structure *n*=0.05

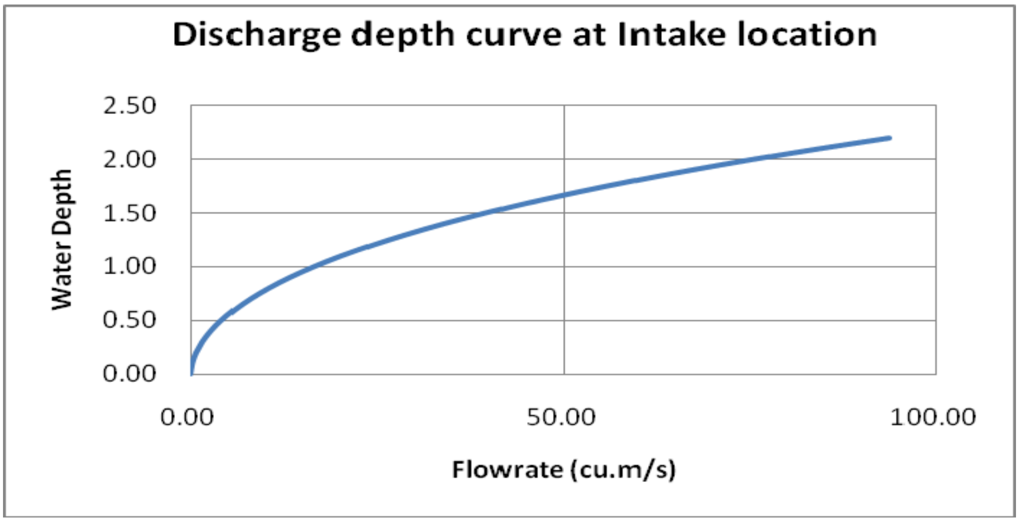
Channel Dimensions			
Bed Width (b):	1.50	m	
Side Slope (s):			
L	0.6	R	0.5
Bed level	529.48	m OD	
Channel Slope:	1.250E-01		0.125
Start Depth	0	m	
n:	0.05	torrential rivers with beds covered with boulders	
dh	0.1	m	
Flow Rate:	0.245	m^3/s	

Normal Depth (h) m	Flow Area (A) m^2	Wetted Perimeter (P) m	Hydraulic Radius (R) m	R^(2/3)	Flow Rate (Q) m^3/s	Velocity m/s	WS level m OD	TEL m OD
0.00	0.00	1.50	0.00	0.00	0.00	0.00	529.48	529.48
0.10	0.17	1.92	0.09	0.20	0.24	1.40	529.58	529.68
0.20	0.37	2.34	0.16	0.29	0.78	2.08	529.68	529.90
0.30	0.62	2.75	0.22	0.37	1.60	2.60	529.78	530.13
0.40	0.89	3.17	0.28	0.43	2.71	3.04	529.88	530.35
0.50	1.21	3.59	0.34	0.48	4.13	3.42	529.98	530.58
0.60	1.56	4.01	0.39	0.53	5.88	3.77	530.08	530.80
0.70	1.95	4.43	0.44	0.58	7.97	4.09	530.18	531.03
0.80	2.37	4.84	0.49	0.62	10.43	4.39	530.28	531.26
0.90	2.84	5.26	0.54	0.66	13.27	4.68	530.38	531.50
1.00	3.33	5.68	0.59	0.70	16.52	4.96	530.48	531.73
1.10	3.87	6.10	0.63	0.74	20.20	5.22	530.58	531.97
1.20	4.44	6.52	0.68	0.77	24.31	5.48	530.68	532.21
1.30	5.05	6.93	0.73	0.81	28.89	5.72	530.78	532.45
1.40	5.69	7.35	0.77	0.84	33.95	5.96	530.88	532.69
1.50	6.38	7.77	0.82	0.88	39.51	6.20	530.98	532.94
1.55	6.73	7.98	0.84	0.89	42.48	6.31	531.03	533.06
1.60	7.09	8.19	0.87	0.91	45.58	6.43	531.08	533.18
1.70	7.85	8.61	0.91	0.94	52.19	6.65	531.18	533.43
1.80	8.64	9.02	0.96	0.97	59.35	6.87	531.28	533.69
1.90	9.47	9.44	1.00	1.00	67.08	7.08	531.38	533.94

From the above calculations it can be seen that for the 1 in 50 year flood flow of 42.24 m^3/s, the river would reach a depth of 1.55m above the existing bed level of 529.48 m AOD, assuming that the bank profile was not altered.

The depth flow graph (fig 23) indicates how the flow through the intake varies with depth.

FIG 23: Depth Flow chart for 1 in 50 yr flood at intake site



In reality, the installation of the intake structure would require the construction of protective head walls to prevent scour erosion and damage to the intake chamber and pipeline. This however must be considered relative to available budget

5.8 Design Parameters to be used for the Irrigation System Design

From the Crop Water Requirement Report and the Hydrology Report the following Design Parameters can now be taken forward to the detailed design of the main elements of the Irrigation system design:

- Average Crop Water Requirement 5.6 mm/day
- Gross Crop water requirement 7.07 mm/day
- Gross water application = 1.637 l/s/ha
- Residual Head available at the delivery point = 30 m
- Intake location coordinates N 15° 30.798' W 061° 25.615', altitude 530 m asl.
- Intake to be designed for an off-take peak of 20 l/s (20 ha in 2 cycles)
- Peak flood flow at intake 42.24 m^3/s

VOLUME 3

HYDRAULIC STRUCTURE

6. HYDRAULIC STRUCTURES

6.1 Water Intake Structure

The intake structure foreseen must provide for the effective extraction of the required volumes of water (16.7 l/s), while being able to withstand the 1: 50 yr flood event (42.24 m^3/s). The situating of the structure high within the river profile, (Coordinates: N 15° 30.798' W 061° 25.615' – on State Lands) provides some guarantee of reduce human activity thus negating the requirement for specialized modifications required to safeguard against excessive silt load and other debris.

The location selected is however characterised by an abundance of leaves and sometimes branches and trees within the main course of the river. These can often caused disruption (blockage of flow) in traditional intake structures increasing the need for frequent maintenance.

The variability of the flow of the river on which the intake is located is well noted. The proposed intake structure must therefore perform optimally in cases of high and low water flows.

The intake structure foreseen therefore consists of a main conveyance chamber with an inlet grating made of stainless or other type of Hot dipped galvanized steel. The chamber will contain a hollow central core for conveyance and will be constructed of reinforced concrete. The finish elevation of the intake weir walls differs so that the grating is sloped to remove an optimum volume of water through its perforations, while allowing for self cleansing of leaves etc by the main river flow. The water leaves the chamber and enters a baffled sedimentation basin where suspended solids will be removed in one area and de-sanded water enters the second compartment then flows into the transmission line. A sluice gate exists within the settling basin to control outflows to the transmission line. The settling basin will also be constructed of reinforced concrete.
All concrete is foreseen to have a minimum 28 day compressive strength of 35 MPa.

6.2 Pipe

The hydraulic calculations for the various pipe sizes are contained in Annex 2.
A mixture of ductile iron, Polyethylene and PVC pipes are foreseen to be used to conduct the water from the source to the command area. Pipes laid within the flood pain and river

channel will be galvanized and or ductile iron, suitably anchored. Approximate proposed pipe alignment is shown in fig 26.

6.3 Water Treatment/ Filter Station

The physical water quality at the intake site will require further testing to determine the chemical contaminants. These results will further inform the need for specialised treatment.

Periodic occurrence of flooding associated with heavy rains and the accompanying erosion usually experienced, however dictates that some form of filtration be incorporated into the conveyance system. This filtration system becomes particularly important, as the recommendation is to utilize either drip or micro sprinklers as water delivery systems.

Both drip and Micro sprinklers are very prone to blockage from debris, thus affecting their effective functioning. Batched Sand media (see fig 24) and Disc filters will be distributed in the manner indicated in the schematic of the network, Annex 3. The filter assembly will be designed to be inline pressure filters contained in epoxy treated steel containers and completely automated self-cleansing.

6.3.1 Media Filters:

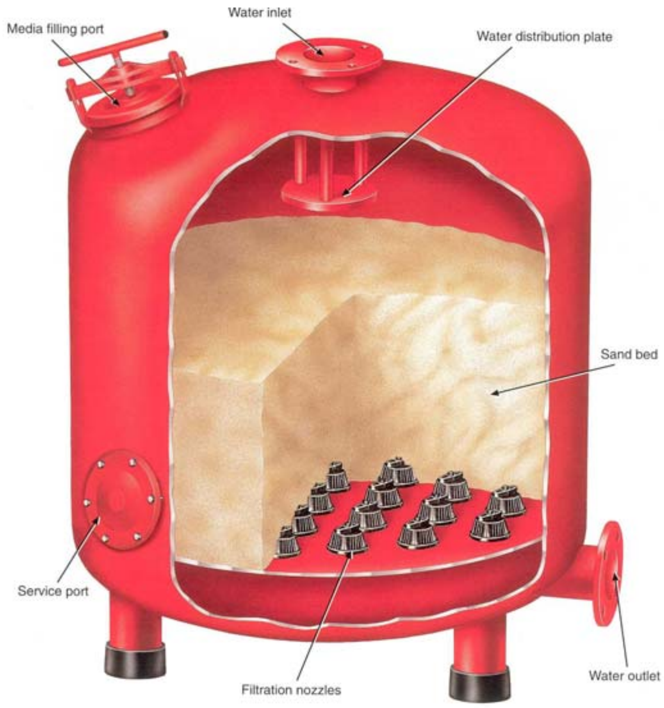
Media filters perform the filtration of water through a thick layer of graded particles. These particles can be sand, gravel or other granular materials. The filtration rate depends on the effective size of the bedding and the velocity through the filter.

Water enters through the filter inlet and percolates through the filter bed. When suspended matter comes in contact with media particles, it adsorbs on it. Clean water then goes via the filtration nozzles through the filter outlet.

Cleaning is achieved via back washing. Water is passed in the reverse direction – from the nozzles upwards, causing the suspension of the filter bed, thus releasing the suspended matter that is then flushed out through the backwash valve.

The media for filtration will be graded sand followed by fine disc filter of approximately 130 microns. Filters will be sized to adequately meet filtration capacity while allowing minimal pressure lost across the media.

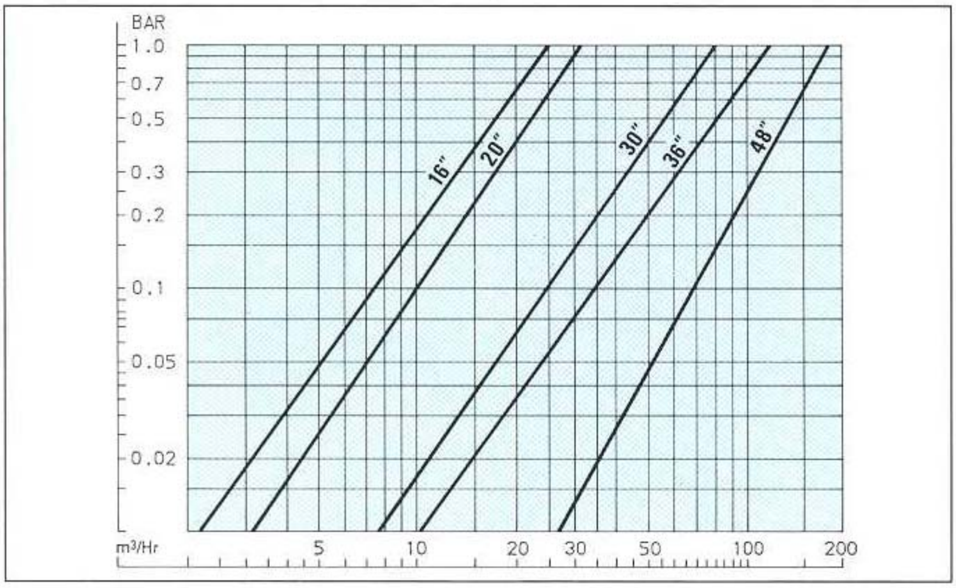
FIG 24: Typical Sand Media Filter Assembly



6.3.1.1 Head losses through the Media Filter

The key design parameter required when selecting the correct size of filter is the pressure head loss for the selected flow. Fig 25 below indicates the head loss through media filters of different diameters at different flows.

FIG 25: Performance chart for graded sand media filters



6.3.1.2 Screen Filters:

Screen filters are germane to a wide range of filtering applications and filtration degrees and are easy to install and maintain. The carbon steel housing is protected with a polyester coating; no tools are required for dismantling or for extracting the filter element from the filter housing for rinsing, and also visual monitoring of the status of the filter element without disrupting the water flow is easily done with the clogging indicator connected to the filter's pressure checkpoints.

The installed disc elements provide high retention of organic substances and are constructed from plastic discs that are stacked onto a telescopic core. The direction of flow in these elements is from the outside in along the element, therefore the effective area is comprised of both the outside surface and the channels formed by the intersected grooves. Suspended organic particles adhere to the grooved surface adding depth to the filtration process.

Cleaning the disc element is made simple by the unique design of the telescopic core that allows the discs to separate during the cleaning process. For the purposes of the Milton Irrigation Scheme, where trickle irrigation and micro-sprinklers is recommended, a mesh size of 120 is foreseen, this relates to filtration to 130 Microns.

The calculations of flow rates for the Filter station indicated on the schematic diagram (Annex 3) were used to select the most effective combination of filters to minimise the total head losses through the station, (see table 19).

Table 19: Specifications of Filter Stations

Location	Flow **l/s**	Flow in m^3/hr	**Type and No of Media Filters**	**Head loss**	**Type and No of Screen Filters**	**Head loss**
At Chainage 1159m	32.76	118	2 x 36" sand Filter	1.0m (2.0)	2x 10" in-line screen	0.5m (1.0)

The head loss figures were adapted from relevant head loss curves in the Amiad Filtration systems catalogues. These head losses assumes that the filters are running clean. The figures in brackets were modified to represent average head losses between backwash cycles by multiplying the given values by a factor of 2.

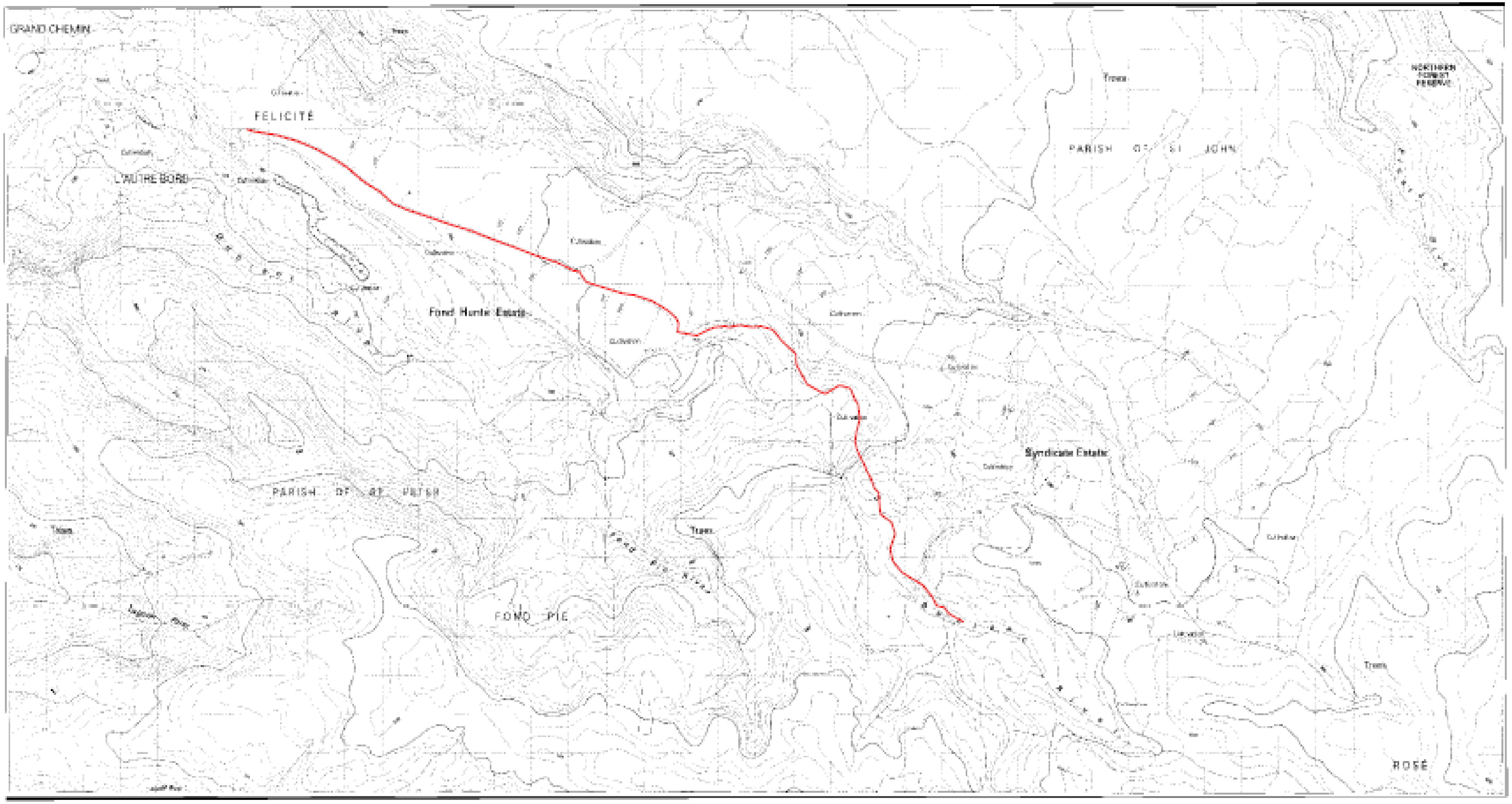


FIG 26: Proposed Pipeline Alignment

VOLUME 4

COST ESTIMATES

7. MILTON COST ESTIMATES

		Milton - Cost Estimate				
Total area	20	ha	49.4	acres		
On farm costs :						
Include PE Submain, manifold, lateral pipes and associated fittings and controls						**Total**
Average cost EC$/acre			7350			**$367,500.00**
Off farm costs:						
Filter units/PE & DI pipe work/Fittings/Main line control valves/Air valves/Tail drains/Control and Distribution Heads/Pressure Regulating Valves.						
Average cost EC$/m			$175.00		**Total**	**$456,000.00**

VOLUME 5

IMPACT ASSESEMENT

8. IMPACT ASSESSMENT

8.1 Economic Impact

The propose irrigation scheme is intended to serve 20 Ha of Agricultural land in the Milton area which presently receives 100% of their crop water requirement from rainfall.

Further analysis of information presented in fig 9, reveals that overall crop benefit would accrue from the provision of water via irrigation from the months of January to July, where water deficits occur. Deficits that are less than 10 mm/ month considered negligible. The benefit to the crop productivity is expected to be in the region of 23% as estimated by the following relationship:

$$1.3 \text{ X } (\text{deficit/potential crop Etc}) = 1.3 \text{ X } 313/1801.5 = 22.6\ \% \approx 23\%$$

Actual production data for the Milton area or other irrigated zones in Dominica was not available at the time of reporting to verify analysis on potential yield improvement. However, if 50% the total acreage to be irrigated is to be cultivated with Bananas then based on an average area yield of 9 tonnes per acre, the provision of irrigation would cause an increase of an additional 2 tonnes per acre i.e. an additional 50 tonnes. This would have significant impact on the level of production nationally and the viability of the Fair-trade Banana Industry.

8.2 Environmental Impacts

The water intake of the propose irrigation scheme will be constructed on State lands approximately 300 m from motorable access within the Milton agricultural catchment area. The area concerned is designated as a farming zone and thus water quality will be affected by agricultural production activity. Prescribed buffer zone of approximately 5 m is however instituted in this area and will afford some level of protection to the water source.
The installation of approximately 2605 m of pipeline from the intake to the project area through a mix of primary rainforest and farmland is expected to be minimally disturbing. Most of the pipe will be placed on the surface thus minimizing the potential for washing of soil into the main stream of the Dublanc River. Removal of trees over 0.6 m in diameter is accessed as unlikely, so does the need for significant soil disturbance.

While the area is described as having Nil to moderate susceptibility to erosion, based on Lang (1967) classification Soils (fig 26) and Erosion hazard (fig 27) this classification increases to moderated high as slopes increases and the primary cover is compromised. The required under brushing and removal of shrubs to effect the pipe laying operations will serve to increase erosion risk especially of slopes exceeding 25%. This situation will most likely significantly affect DOWASCO's portable water supply to the Dublanc area. In fact, close collaboration will be required with the personnel of DOWASCO to ensure that disruption of service remains at an absolute minimum and filling of storage do not occur during periods of work within the vicinity of the river.

DOWASCO is also the entity with ultimate rights over water resource on island. It will therefore be necessary for the Ministry of Agriculture to seek the necessary permission for the extraction of water from the proposed water source.

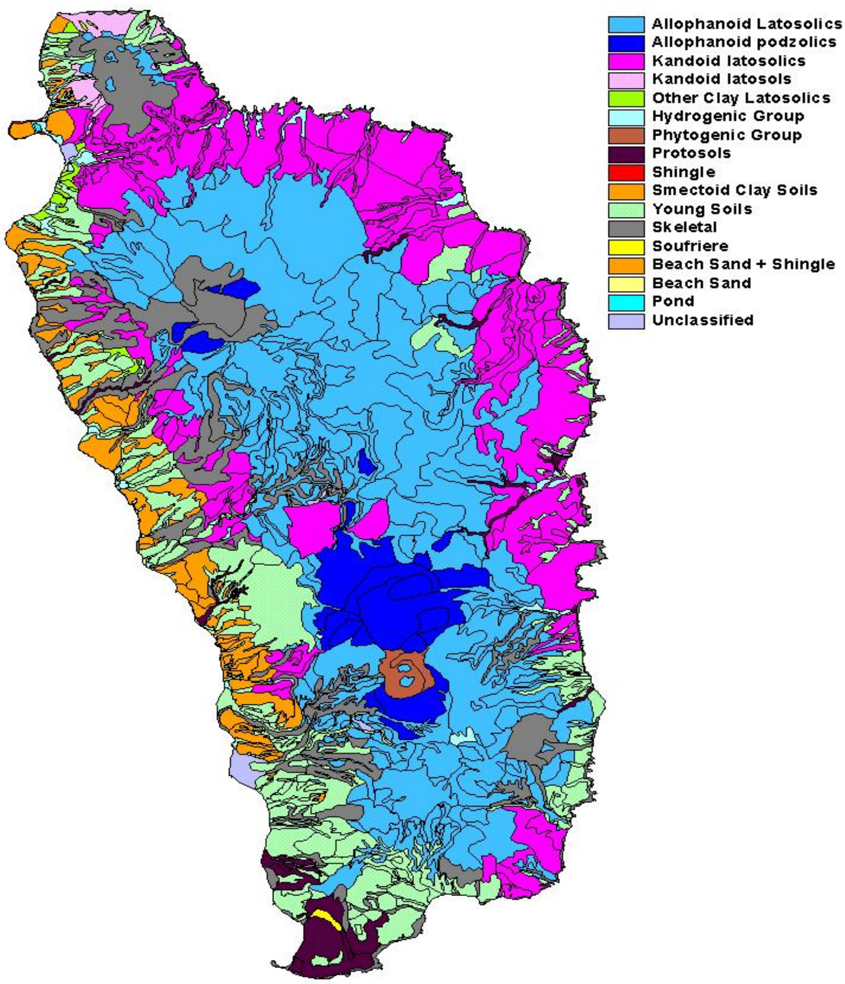


FIG 28: Soil Classification Map (Lang,1967)

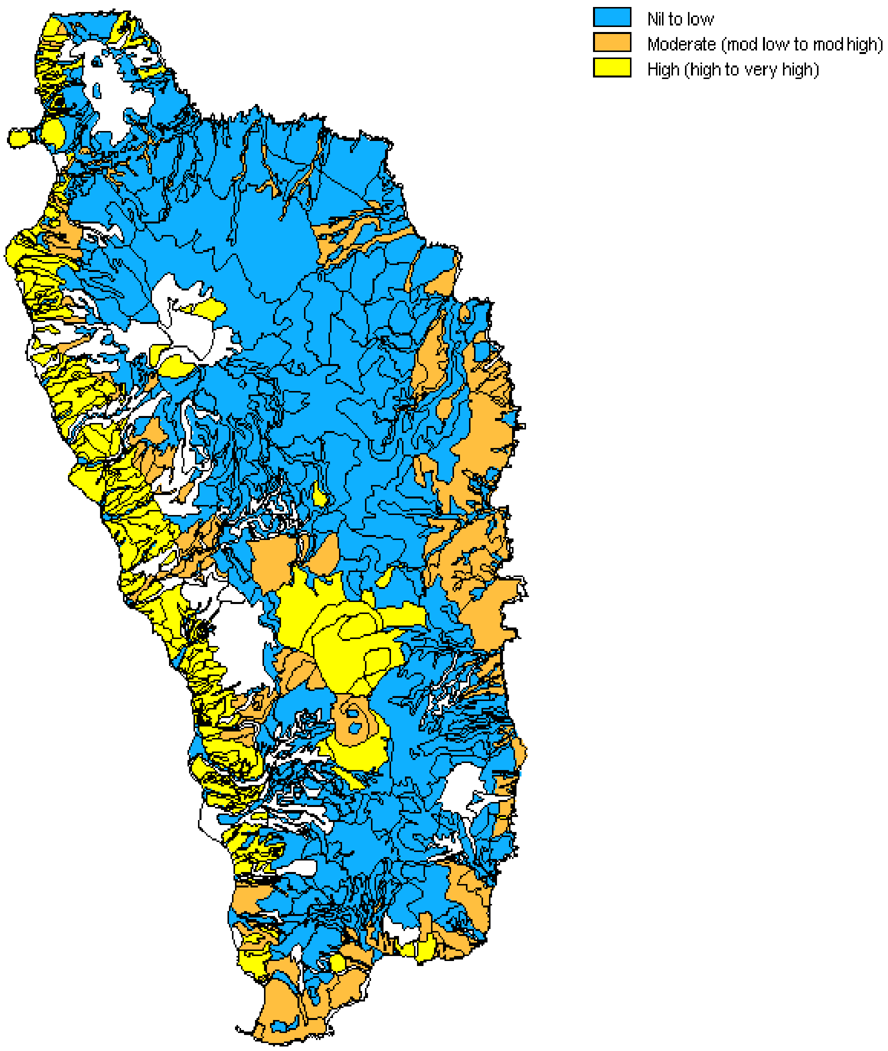


FIG 29: Relative soil erosion hazard mapping (Lang, 1967)

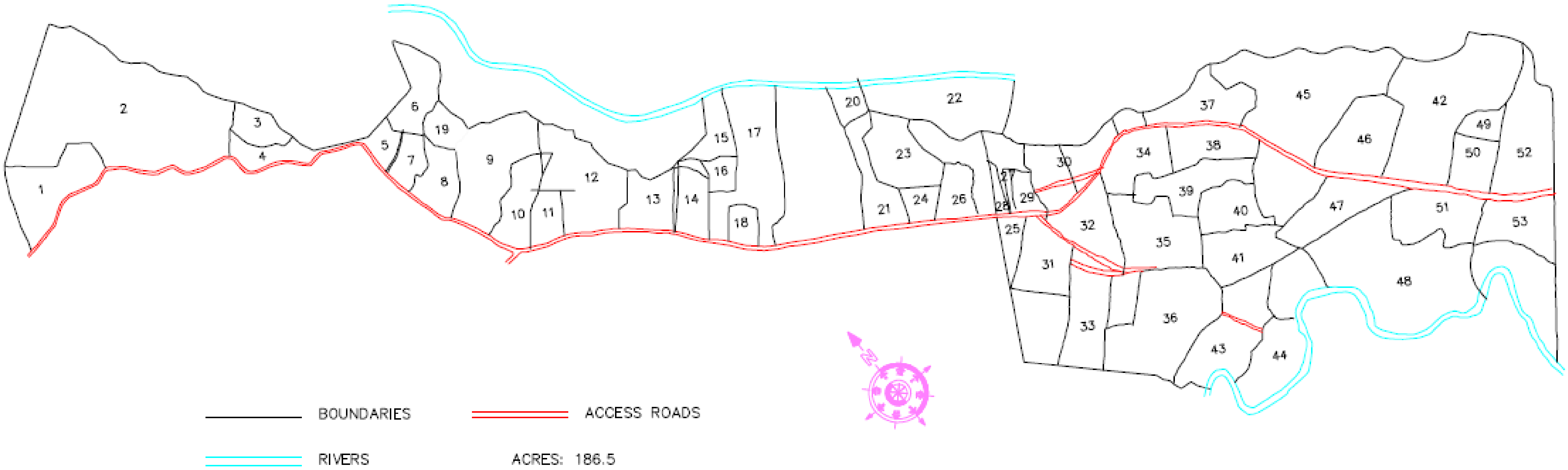
The effects on flora and fauna within the locale is expected to be minimal and short lived, extending essentially during the construction phase and shortly thereafter. The maintenance of a dirt track needed for installation of the pipe and for continued maintenance will increase the risk of traffic within the area. This can however be modulated into a nature trail with established protocols for usage.

Easement arrangements will be required to be concluded with land owners; Heirs of Derrick Jeffrey and Russell Bertrand for placement of pipeline. The cooperation of Curtis Charles and heirs of Derrick Jeffrey will also be required to facilitate access to the intake.

VOLUME 6

ANNEXES

ANNEX 1: MILTON SUB-DIVISION



Land Owners of the Proposed Area for the Milton Irrigation Pilot Project

No.	Land Owner		Acreage
1	Jefferson Frederick		4.100
2	Clifton Shillingford		18.600
3	Felix Anselm		1.170
4	Felix Anselm		1.300
5	Samuel Joseph		1.100
6	Samuel Joseph		1.860
7	Myers Gussie		0.710
8	Peter Gussie		2.270
9	William Pierre-Louis		7.825
10	Jefferson Frederick		2.450
11	Anthony Frederick		1.500
12	Aran Gabriel & Chrisellia Gabriel		5.450
13	Earl Larocque		2.050
14	Norman Shillingford - Whitnel Louis		2.000
15	Roy Bertrand		1.720
16	Roy Bertrand		0.750
17	Clement Augustus Charles		6.150
18	Roy Bertrand		0.870
19	Myers Gussie		1.630
21	McNeil Casimir		3.150
23	Jeffers Morancie & Sybil Sylvester - Conrad James		3.000
24	Cummings Shillingford		1.080
25	Keith Pierre-Louis		0.830
26	Doreen Shillingford		1.400
27	Kirby Shillingford		1.680
28	Kirby Shillingford		1.680
29	Cuthbert Shillingford		3.000
30	Julius C. Caesar		1.240
31	Carlton Shillingford		3.800
32	Iving Shillingfod		2.700
33	Alwin Shillingford		3.150
34	Kent Casimir		3.200
35	Israel Preire Louis		3.700
36	Richmond Shillingford		5.975
37	Anselm Bertand		2.150
38	Roy Bertrand		1.040
39	John Nicholas		2.750
40	Addison Casmir		1.600
41	Craytom Survey		1.850
43	Cuthbert Corbette		2.650
44	Hanson Peter		2.350
45	Desmond Bertrand		7.700
46	Bellot Shillingford		3.550
47	Cummings Shillingford		2.850
48	Israel Preire Louis		9.900
49	Cummings Shillingford		0.795

No.	Land Owner		Acreage
50	Cummings Shillingford		1.700
51	Carlton Shillingford		2.700
52	Mervin Shillingford		7.900

ANNEX: 2 HYDRAULIC CALCULATION- 2 CYCLE OF 10 HA/CYCLE

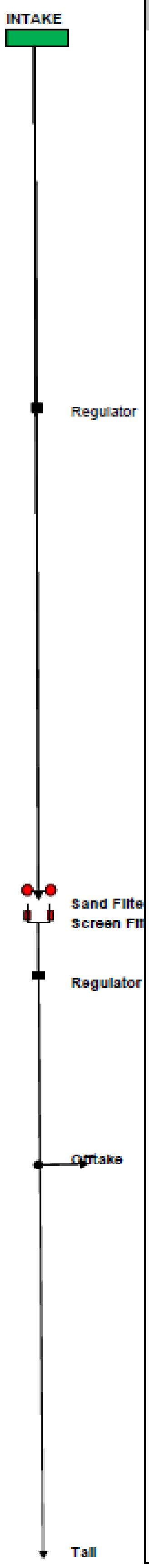
HYDRAULIC CALCULATION

$Hf=0.628LD^{-4.865}[100Q/C]^{1.852}$ where: D is diameter in mm, Q=flowrate in litres/hour

PVC 145 PE 150

	distance (m)	chainage (m)	altitude (m)	main pipe flow (l/s)	nominal diameter (mm)	diameter (mm)	headloss (m)	Minor losses (m)	Pressure Reg. (m)	pressure (m)	Static Head (m)	Offtake area (ha)	Offtake flow (l/s)
INTAKE	0.00	0.00	530	16.70	125.00	113.00	0.00	0.00		0.00	0.00	10.00	16.70
	44.80	44.80	526.1	16.70	125.00	113.00	0.97	0.10		2.84	3.90		
	17.60	62.40	525.5	16.70	125.00	113.00	0.38	0.04		3.02	4.50		
	21.70	84.10	524.7	16.70	125.00	113.00	0.47	0.05		3.30	5.30		
	26.40	110.50	520.1	16.70	125.00	113.00	0.57	0.06		7.28	9.90		
	37.10	147.60	516.8	16.70	125.00	113.00	0.80	0.08		9.69	13.20		
	17.60	165.20	515.6	16.70	125.00	113.00	0.38	0.04		10.48	14.40		
	36.90	202.10	512.4	16.70	125.00	113.00	0.80	0.08		12.80	17.60		
	15.80	217.90	511.1	16.70	125.00	113.00	0.34	0.03		13.72	18.90		
	35.50	253.40	508.6	16.70	125.00	113.00	0.77	0.08		15.38	21.40		
	33.10	286.50	506.3	16.70	125.00	113.00	0.71	0.07		16.89	23.70		
	41.90	328.40	507	16.70	125.00	113.00	0.90	0.09		15.20	23.00		
	31.00	359.40	504.3	16.70	125.00	113.00	0.67	0.07		17.16	25.70		
	33.60	393.00	505.5	16.70	125.00	113.00	0.73	0.07		15.16	24.50		
	16.20	409.20	510.1	16.70	125.00	113.00	0.35	0.03		10.18	19.90		
	39.80	449.00	504.5	16.70	125.00	113.00	0.86	0.09		14.83	25.50		
	16.10	465.10	504.8	16.70	125.00	113.00	0.35	0.03		14.15	25.20		
	30.00	495.10	508.5	16.70	125.00	113.00	0.65	0.06		9.74	21.50		
	24.30	519.40	493.3	16.70	125.00	113.00	0.52	0.05		24.36	36.70		
Regulator	5.00	524.40	449.3	16.70	125.00	113.00	0.11	0.01	30.00	30.00	80.70		
	34.40	558.80	438.8	16.70	125.00	113.00	0.74	0.07		39.68	91.20		
	3.70	562.50	435.1	16.70	125.00	113.00	0.08	0.01		43.29	94.90		
	14.70	577.20	437.5	16.70	125.00	113.00	0.32	0.03		40.55	92.50		
	19.40	596.60	434.1	16.70	125.00	113.00	0.42	0.04		43.48	95.90		
	25.90	622.50	430.9	16.70	125.00	113.00	0.56	0.06		46.07	99.10		
	32.60	655.10	429.2	16.70	125.00	113.00	0.70	0.07		47.00	100.80		
	30.90	686.00	425.9	16.70	125.00	113.00	0.67	0.07		49.56	104.10		
	8.40	694.40	419.8	16.70	125.00	113.00	0.18	0.02		55.46	110.20		
	8.90	703.30	421.4	16.70	125.00	113.00	0.19	0.02		53.65	108.60		
	34.80	738.10	418.3	16.70	125.00	113.00	0.75	0.08		55.92	111.70		
	18.90	757.00	419.6	16.70	125.00	113.00	0.41	0.04		54.17	110.40		
	13.00	770.00	418.5	16.70	125.00	113.00	0.28	0.03		54.97	111.50		
	42.30	812.30	416.7	16.70	125.00	113.00	0.91	0.09		55.76	113.30		
	12.50	824.80	421	16.70	125.00	113.00	0.27	0.03		51.16	109.00		
	40.20	865.00	419.6	16.70	125.00	113.00	0.87	0.09		51.61	110.40		
	51.20	916.20	429.5	16.70	125.00	113.00	1.11	0.11		40.49	100.50		
	9.90	926.10	429.1	16.70	125.00	113.00	0.21	0.02		40.66	100.90		
	25.50	951.60	430	16.70	125.00	113.00	0.55	0.06		39.15	100.00		
	27.50	979.10	432.4	16.70	125.00	113.00	0.59	0.06		36.10	97.60		
	24.20	1003.30	432	16.70	125.00	113.00	0.52	0.05		35.92	98.00		
	36.30	1039.60	430.1	16.70	125.00	113.00	0.78	0.08		36.96	99.90		
	33.30	1072.90	427.5	16.70	125.00	113.00	0.72	0.07		38.77	102.50		
	22.40	1095.30	426.7	16.70	125.00	113.00	0.48	0.05		39.04	103.30		
	33.70	1129.00	424.9	16.70	125.00	113.00	0.73	0.07		40.04	105.10		
Sand Filter	30.20	1159.20	426	16.70	125.00	4 x FAV4	2.50	0.25		36.19	104.00		
Screen Filter	10.40	1169.60	426.4	16.70	125.00	4 x FMY4	2.50	0.25		33.04	103.60		
	28.30	1197.90	421.4	16.70	125.00	113.00	0.61	0.06		37.37	108.60		
	25.30	1223.20	416	16.70	125.00	113.00	0.55	0.05		42.16	114.00		
Regulator	26.80	1250.00	410.3	16.70	125.00	113.00	0.58	0.06	30.00	30.00	119.70		
	52.20	1302.20	402	16.70	125.00	113.00	1.13	0.11		37.06	128.00		
	22.80	1325.00	401.4	16.70	125.00	113.00	0.49	0.05		37.12	128.60		
	17.00	1342.00	400.5	16.70	125.00	113.00	0.37	0.04		37.61	129.50		
	24.40	1366.40	398.4	16.70	125.00	113.00	0.53	0.05		39.13	131.60		
	51.80	1418.20	394.8	16.70	125.00	113.00	1.12	0.11		41.50	135.20		
	49.60	1467.80	392.2	16.70	125.00	113.00	1.07	0.11		42.93	137.80		
	34.30	1502.10	391	16.70	125.00	113.00	0.74	0.07		43.31	139.00		
	60.50	1562.60	387.3	16.70	125.00	113.00	1.31	0.13		45.57	142.70		
	39.10	1601.70	385.2	16.70	110.00	99.40	1.58	0.16		45.94	144.80	3.00	4.90
Offtake	32.60	1634.30	385.2	11.80	110.00	99.40	0.69	0.07		45.18	144.80		
	12.70	1647.00	385	11.80	110.00	99.40	0.27	0.03		45.09	145.00		
	51.50	1698.50	384.1	11.80	110.00	99.40	1.09	0.11		44.79	145.90		
	60.50	1759.00	382	11.80	110.00	99.40	1.28	0.13		45.48	148.00		
	121.10	1880.10	377.8	11.80	110.00	99.40	2.57	0.26		46.85	152.20		
	60.60	1940.70	375.7	11.80	110.00	99.40	1.28	0.13		47.54	154.30		
	60.60	2001.30	373.5	11.80	110.00	99.40	1.28	0.13		48.33	156.50		
	60.50	2061.80	371.4	11.80	110.00	99.40	1.28	0.13		49.02	158.60		
	60.60	2122.40	370.4	11.80	110.00	99.40	1.28	0.13		48.61	159.60		
	40.30	2162.70	370.4	11.80	110.00	99.40	0.85	0.09		47.67	159.60		
	43.40	2206.10	368.5	11.80	110.00	99.40	0.92	0.09		48.56	161.50		
	60.50	2266.60	365.8	11.80	110.00	99.40	1.28	0.13		49.85	164.20		
	53.50	2320.10	364.4	11.80	110.00	99.40	1.13	0.11		50.00	165.60		
	33.60	2353.70	363.6	11.80	110.00	99.40	0.71	0.07		50.02	166.40		
	30.00	2383.70	363	11.80	110.00	99.40	0.64	0.06		49.92	167.00		
	30.60	2414.30	362.5	11.80	110.00	99.40	0.65	0.06		49.71	167.50		
	47.40	2461.70	362.5	11.80	110.00	99.40	1.00	0.10		48.60	167.50		
	60.60	2522.30	362.5	11.80	110.00	99.40	1.28	0.13		47.19	167.50		
	60.50	2582.80	365.7	11.80	110.00	99.40	1.28	0.13		42.58	164.30		
Tail	22.60	2605.40	365.7	11.80	110.00	99.40	0.48	0.05		42.06	164.30		

ANNEX 3: PROPOSED SYSTEM LAYOUT



chainage (m)	altitude (m)	nominal diameter (mm)
0.00	530	125.00
44.80	526.1	125.00
62.40	525.5	125.00
84.10	524.7	125.00
110.50	520.1	125.00
147.60	516.8	125.00
165.20	515.6	125.00
202.10	512.4	125.00
217.90	511.1	125.00
253.40	508.6	125.00
286.50	506.3	125.00
328.40	507	125.00
359.40	504.3	125.00
393.00	505.5	125.00
409.20	510.1	125.00
449.00	504.5	125.00
465.10	504.8	125.00
495.10	508.5	125.00
519.40	493.3	125.00
524.40	449.3	125.00
558.80	438.8	125.00
562.50	435.1	125.00
577.20	437.5	125.00
596.60	434.1	125.00
622.50	430.9	125.00
655.10	429.2	125.00
686.00	425.9	125.00
694.40	419.8	125.00
703.30	421.4	125.00
738.10	418.3	125.00
757.00	419.6	125.00
770.00	418.5	125.00
812.30	416.7	125.00
824.80	421	125.00
865.00	419.6	125.00
916.20	429.5	125.00
926.10	429.1	125.00
951.60	430	125.00
979.10	432.4	125.00
1003.30	432	125.00
1039.60	430.1	125.00
1072.90	427.5	125.00
1095.30	426.7	125.00
1129.00	424.9	125.00
1159.20	426	125.00
1169.60	426.4	125.00
1197.90	421.4	125.00
1223.20	416	125.00
1250.00	410.3	125.00
1302.20	402	125.00
1325.00	401.4	125.00
1342.00	400.5	125.00
1366.40	398.4	125.00
1418.20	394.8	125.00
1467.80	392.2	125.00
1502.10	391	125.00
1562.60	387.3	125.00
1601.70	385.2	110.00
1634.30	385.2	110.00
1647.00	385	110.00
1698.50	384.1	110.00
1759.00	382	110.00
1880.10	377.8	110.00
1940.70	375.7	110.00
2001.30	373.5	110.00
2061.80	371.4	110.00
2122.40	370.4	110.00
2162.70	370.4	110.00
2206.10	368.5	110.00
2266.60	365.8	110.00
2320.10	364.4	110.00
2353.70	363.6	110.00
2383.70	363	110.00
2414.30	362.5	110.00
2461.70	362.5	110.00
2522.30	362.5	110.00
2582.80	365.7	110.00
2605.40	365.7	110.00

ANNEX 4: INDIVIDUALS INTERVIEWED DURING CONDUCT OF STUDY

Name	**Position**	**Organisation**
Samuel Carrette	Permanent Secretary	MOAF
Wallace James	Technical Officer/SPACC Focal point	MOAF
Micheal Thomas	Team Leader - West Extension region	DOA
Dave Lloyd	Business Manager	Dominica National Fair-trade Organisation
Jerome Robinson	Surveyor	
Vivian Eugene	Surveyor	Lands & Survey Department
Arlington James	Forest Officer	DOF
Stephen Durand	Assistant Forest Officer	DOF
Magnus Williams	Chief Engineer	DOWASCO
Pat Vidal	Farmer	
Richmond Shillingford	Farmer – Existing irrigation system	
Curtis Charles	Farmer – Access Road to intake	
Russell Bertrand	Farmer – Pipe Easement	
Mrs Derrick Jeffrey	Land owner – Pipe Easement & Access to Intake	

REFERENCES

SOIL AND LAND-USE SURVEYS NO. 21 DOMINICA, Lang, D.M, 1967.

Crop Water Requirements, FAO Irrigation and Drainage Paper 24, Doorenbos, J., 1984