DRAINAGE REPORT

for

Old Harbour Hill Quarry
Clarendon

May 2009

1 Introduction

1.1 Background

Old Harbour Hill is located at Rose Hall, just north of Freetown in Clarendon. The Partners are proposing to site a quarry in this area. The location plan of the area is shown in Figure 1 1and the proposed extents of the quarry are shown in Figure 2-1

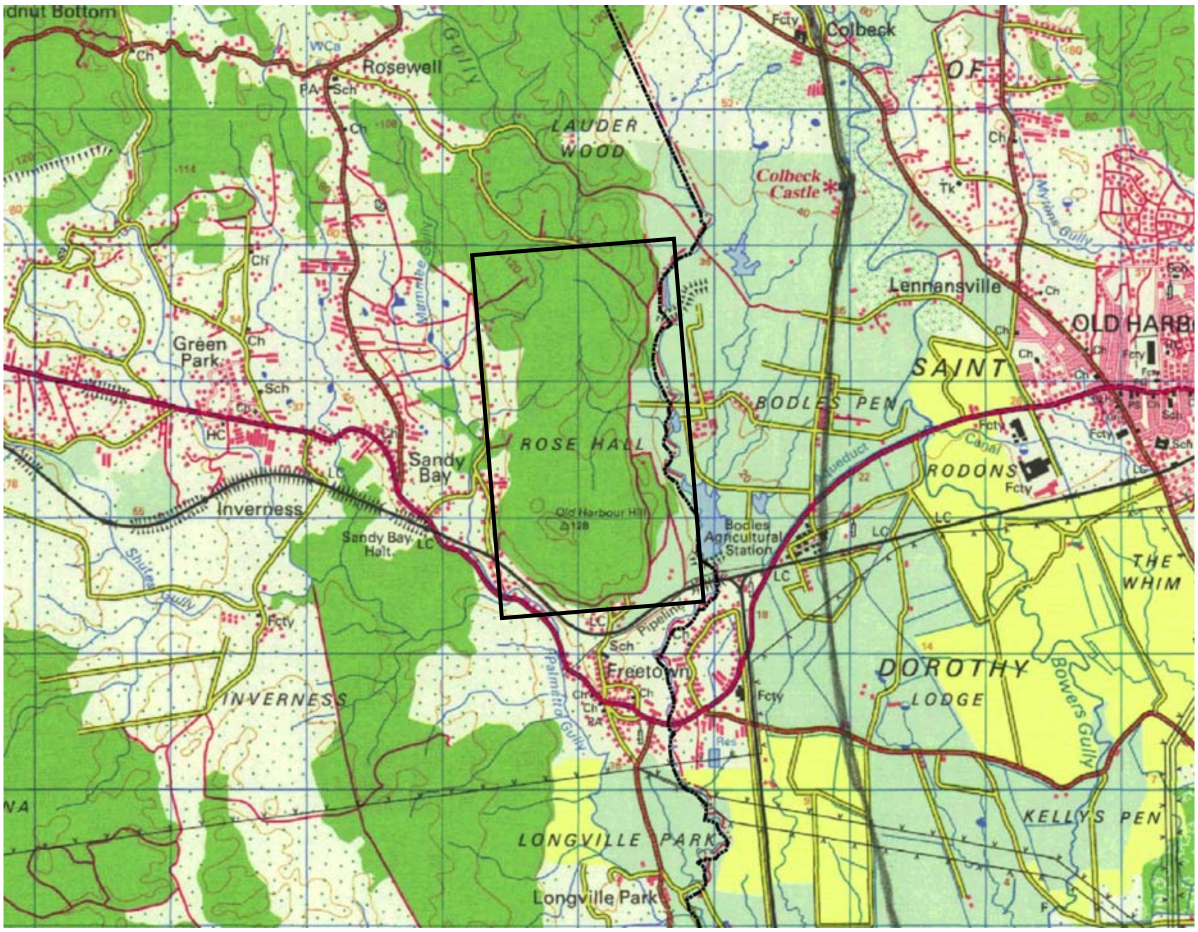

Figure 1-1. 1 in 50,000 map showing location of proposed quarry.

1.2 Objectives of the report

The developer is desirous of developing a drainage plan to ensure minimal impact of the quarry operations on the environment. This drainage plan examined the flow of storm water which will be conducted through these subdivisions.

The goals of this report are as follows:

- To outline the flows expected to be generated from the proposed subdivision.

- To specify drainage requirements works required during mining operations.

1.3 Methodology

The methodology adopted to complete these goals is as follows:

- Field investigations to determine past flooding and rainfall runoff event effects.
- Hydrological analysis of the associated catchments
- Hydraulic analysis of the existing and proposed drains and drainage features
- Engineering Report to NWA guidelines.

2 Description of Areas

At present there is a 22 000 square metre quarry within the overall planned area. Please see Figure 2-1 which shows the location with respect to the site.

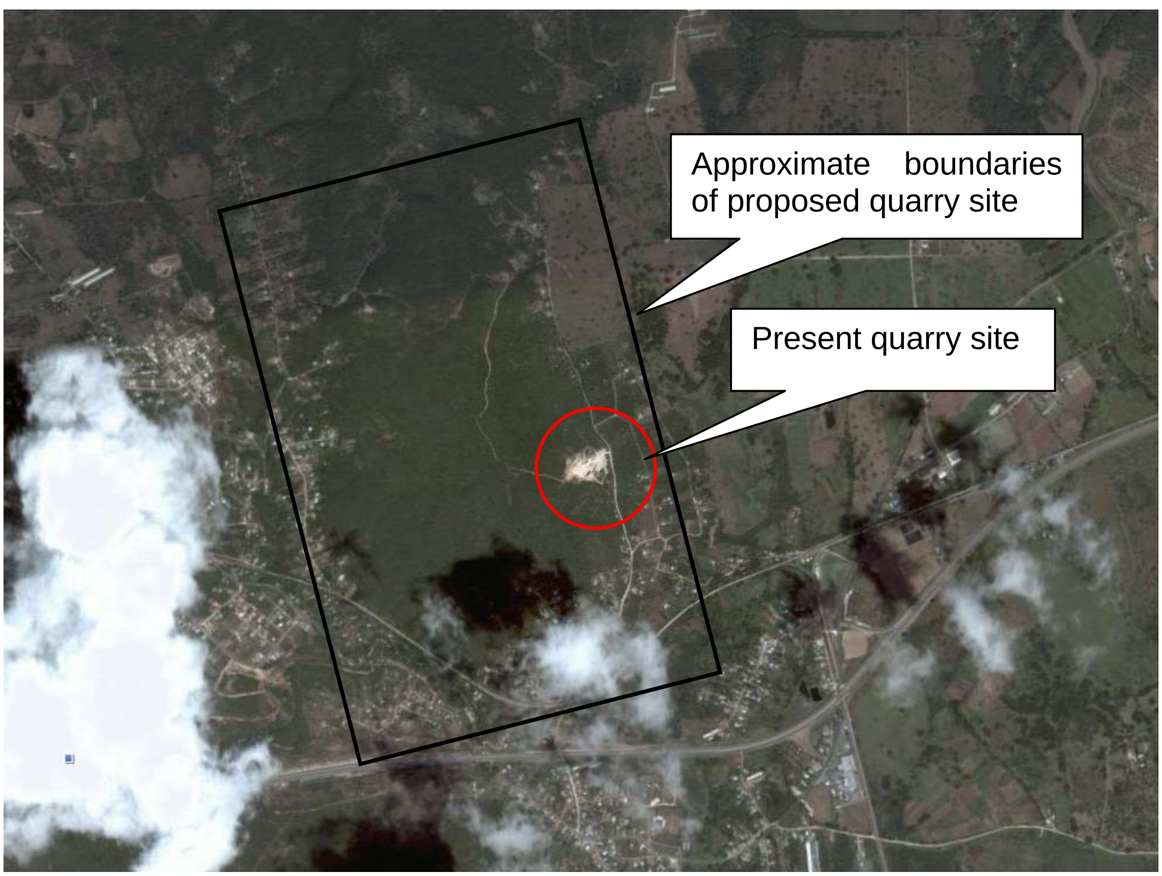

Figure 2-1 Location of present and proposed quarry area on a satelite image of the area

2.1 Topography

Contour data for the proposed sites was obtained from topographic surveys conducted by a commissioned land surveyor. The contour data revealed that the topography of the area is mountainous with moderate slopes. The proposed site is a headland with elevations varying from 118m to 34m above mean sea level. Figure 2 2 shows the contour data obtained superimposed in a satellite image of the site.

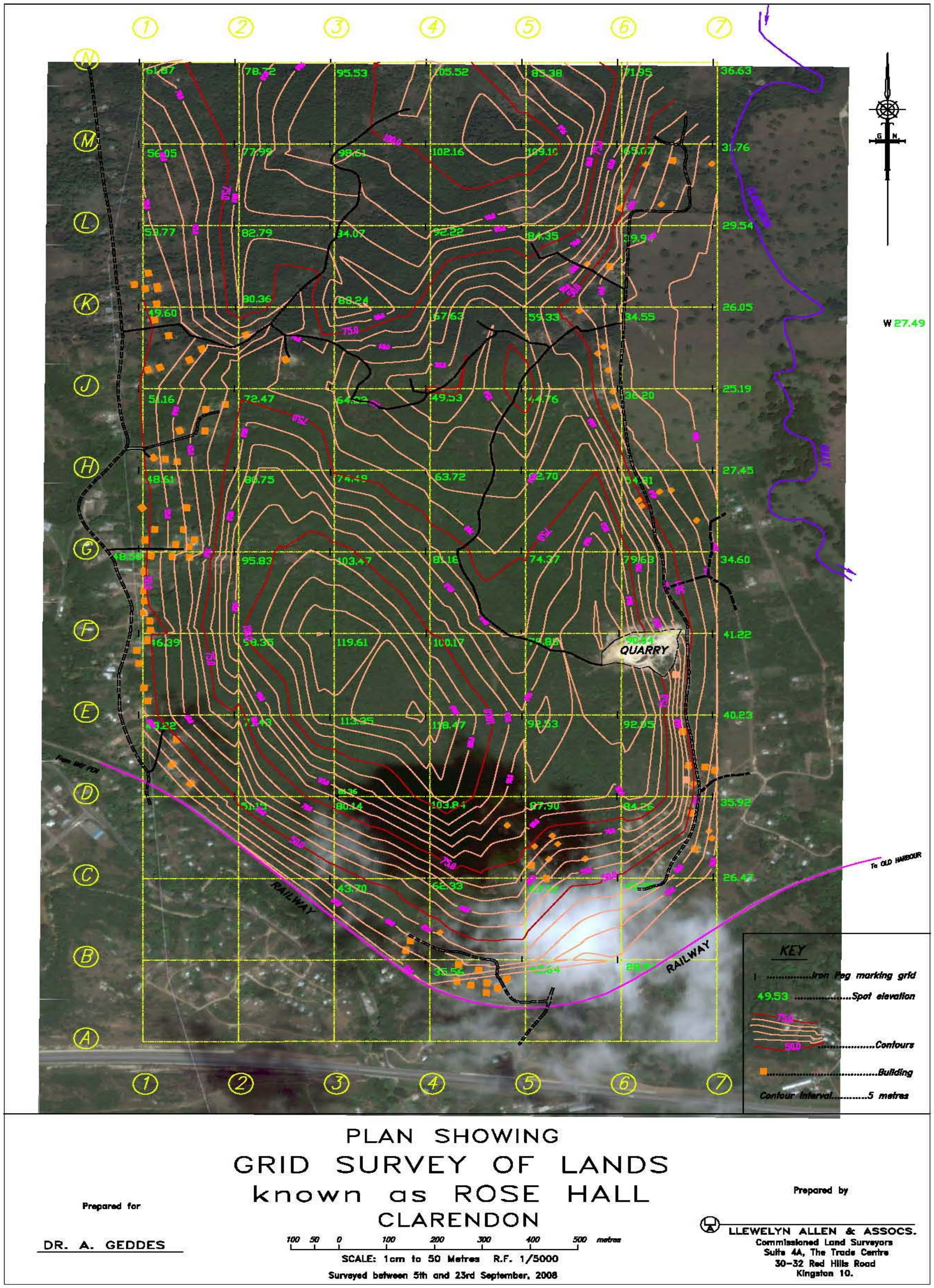

Figure 2-2 Location of present and proposed quarry area on a satelite image of the area

2.2 The Catchments

It was necessary to delineate the catchments associated with the site for development in order to estimate the rainfall runoff expected from the site.

The catchments were delineated using the topographical site data obtained from the surveyor. The site can be divided into three major catchments, eastern catchment, western catchment and southern catchment. Figure 2-3 shows the three major catchment areas.

The eastern catchment encompasses an area of approximately 99.7 hectares (996 938 m^2) and ultimately drains via overland flow to the Clarendon gully located east of the quarry site. See Figure 2-3

The western catchment has an area of approximately 71.8 hectares (718,336 m^2) and drains through three earth swales to the Mammee gully which runs parallel to the western boundary of the property before crossing the Old Harbour main road and discharging into the Palmetto Gully.

The Southern catchment has an area of 53.8 hectares (538,660 m^2) drained in a southerly direction via overland sheet flow. There were no noticeable drainage features draining this catchment which suggests that the land is drained by the existing roads an overland sheet flows to the Palmetto Gully.

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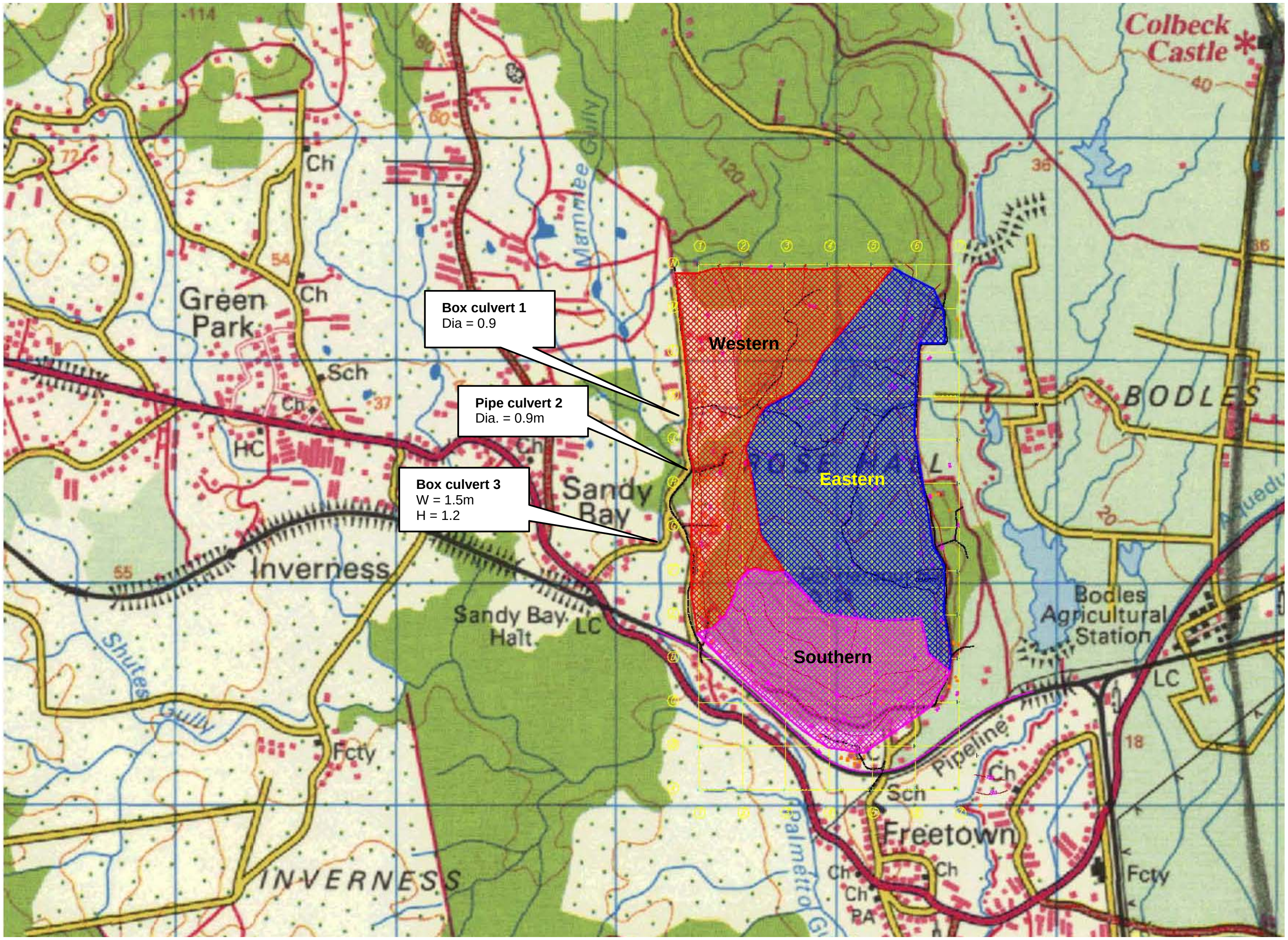

Figure 2-3. Figure illustrates the catchments associated with the site.

2.3 Soils

The soil types as described in the “GIS data sets obtained from the Ministry of Agriculture for the areas contained by the main catchments are sandy loam and stony loam. These soils are rapidly draining soils having a high propensity for landslides. Figure 2-4 illustrates the soil distribution in the area.

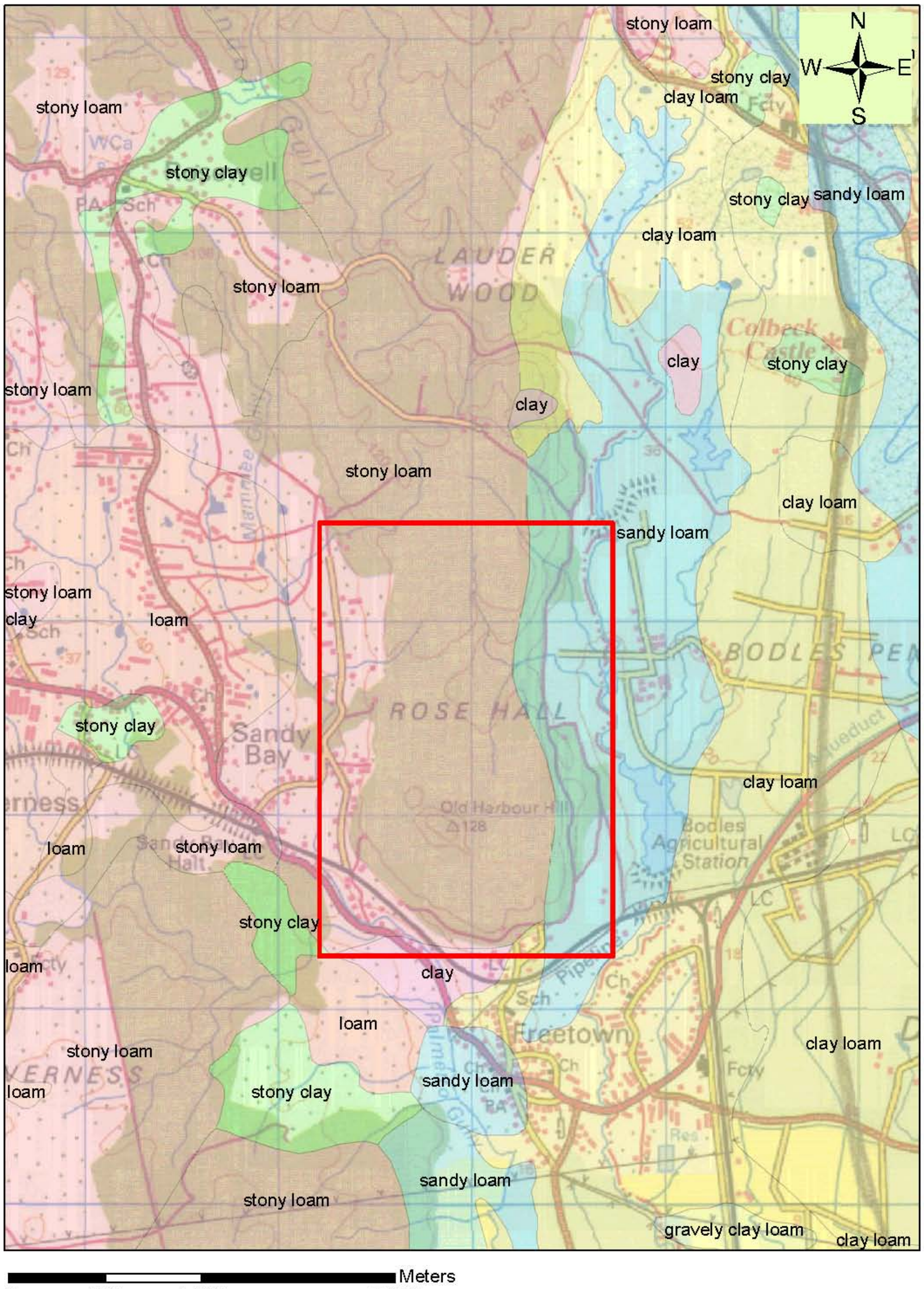

Figure 2-4. Map showing soil types in the area. Red box denotes general property boundary.

2.4 Meteorology

The meteorological data for the catchment was obtained from the Intensity Duration Frequency Curves data set analysed in July 2008 by the Meteorological Service of Jamaica. This data is still being analysed but rainfall data for the closest station, Bodles, was available and used for the analysis. Significant differencies between the new data and the old data set were noticed with increases of 85% recorded. Please see Table 2-1

Table 2-1. Table shows comparison of predicted rainfall intesity between old data and new data.

Return Periods		2	5	10	25	50	100	
Predicted - Rainfall intensity		131	232	302	391	455	518	mm
Previously Predicted - Rainfall intensity		94	140	170	208	236	264	mm
Increase over previous		40%	66%	78%	88%	93%	96%	

Bodles is approximately 1.5km, northeast of the proposed site. The rainfall extremal data was obtained for the 5 year and 50 year return periods as instructed by the NWA guidelines for designing internal drainage and was found to be 230 mm/24hrs and 455 mm/24hrs.

2.5 Anecdotal Evidence of Historical Flooding Events

To supplement meteorological data, information regarding historical rainfall events was obtained by conducting interviews with present residents in the area. On speaking to 5 residents in the area, it was concluded that the eastern side of the proposed site had no historical flooding events even during severe weather systems such as Hurricane Ivan in 2004 and Hurricane Dean in 2007. It was the general consensus that all the rainfall runoff on the eastern side of the property tended to travel over land and on the existing roads to the Clarendon gully which is located to the east of the property and runs from north to south as mentioned earlier. This correlates with the contour data obtained from the 12500 map series generated by the survey department at the National Land Agency of Jamaica.

On the western side of the property, the Mammee gully as mentioned previously was the drainage feature mentioned by the residents as the primary source of conducting rainfall from the area. Residents stated that during extreme rainfall events, Box Culvert 3 which is in a low area has been known to allow flood levels of approximately 0.4m onto the road.

Plate 2.1 Picture showing team member having discussion with resident in the area.

3 Existing Drainage Features

It was important to identify the existing drainage infrastructure so as to analyse the existing capacity as well as the possibility of connection to proposed development. It was also important to deduce the effects of an extremal event so as to predict the water levels expected during flood conditions.

3.1 The Clarendon Gully

The only drainage feature identified was the Clarendon gully which is the general collection feature for all rainfall runoff in the area. Please see Plate 3.1.

Plate 3.1. Picture shows Clarendon gully looking upstream toward culvert under Highway 2000

This gully drains the mountains to the north of the site, continues along the eastern boundary of both developments crossing Highway 2000 via a concrete box culvert (Plate 3.2) and continues south for approximately 1600 metres before joining the Bowers river which discharges into the sea. The general dimensions of the channel are shown in Table 3-1.

Plate 3.2. Concrete culvert under Highway 2000 is the channel for the Clarendon gully.

Table 3-1. Table shows the general dimensions of the Clarendon gully noticed during site visit.

Dimension	Value	Units
Width		
Top of Bank	10	m
Base of Channel	5.5	m
Depth	3.5	m
Slope of Bank	1.5	

Hydrologic analysis of the Clarendon gully and surrounding catchment (please see Figure 3-1) was conducted for the 50 year return period (455 mm/24hrs) as specified by the NWA guidelines mentioned previously for flood control. The results of this analysis predicted that a peak flow of 450.2 cubic metres per second would be expected. In order to handle this peak flow, a channel width (at top of bank) of 21 m and a water depth of 6.25 m would have to be adopted. Please see **Error! Reference source not found.** which conveys these calculations.

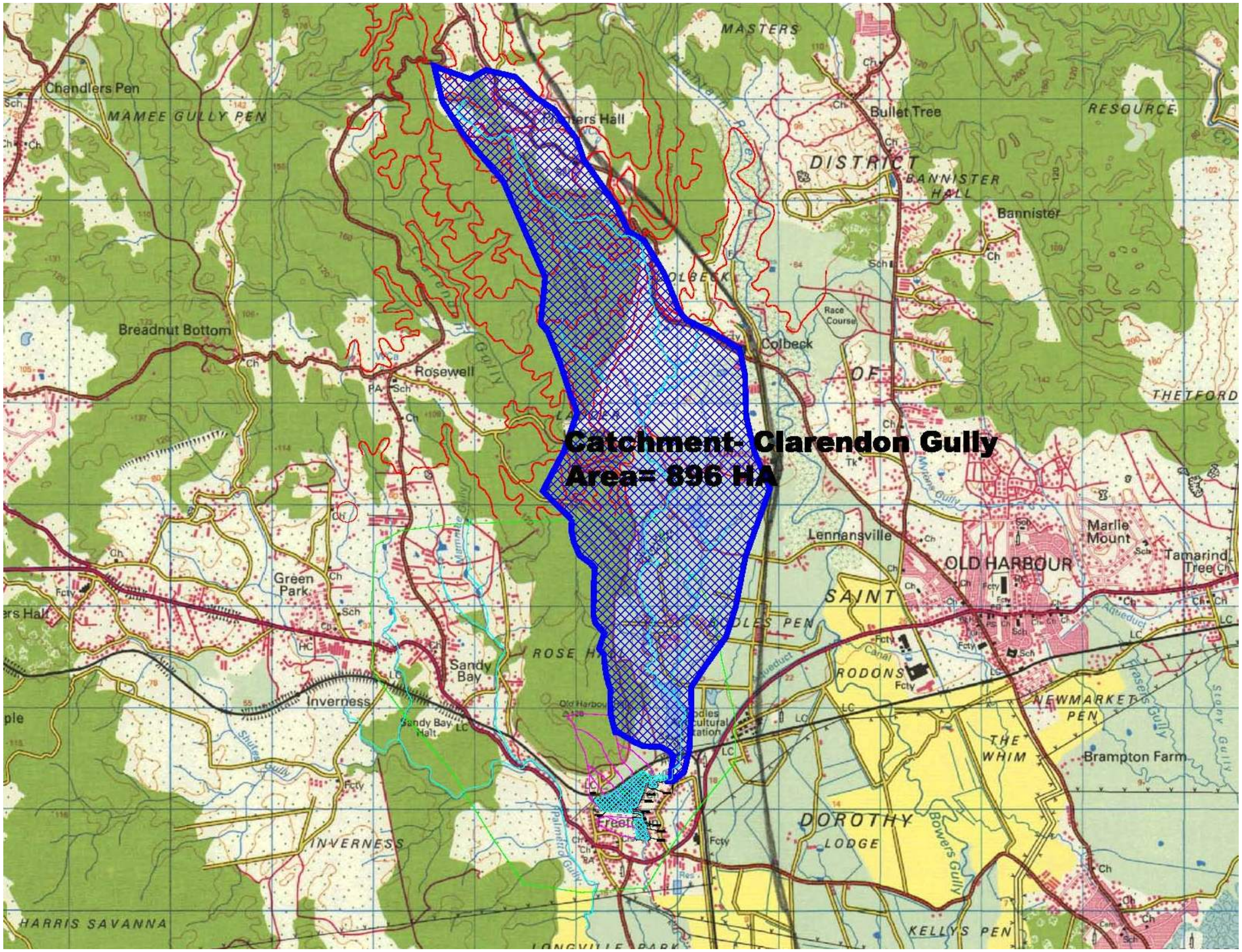

Figure 3-1. Map showing the catchment associated with the Clarendon Gully

It was evident from the hydrologic analysis that the channel presently is not able to accommodate the peak flow expected from the 50 year event. However anecdotal information collected from 5 residents in area surrounding the site conclusively disagree with this prediction. All residents interviewed had no recollection of any flooding from the Clarendon gully.

3.2 The Mammee Gully

The Mammee Gully mentioned earlier runs from north to south along the western boundary of the property. The Gully is the major drainage feature which drains the western side of the property as well as adjacent housing communities in the area. Please see Figure 3-2.

Figure 3-2. Pictures shows Mammee Gully.

The Mammee gully receives runoff from three other drains before discharge south of the property into the Palmetto gully. Please refer to Figure 2-3 which shows the location of these drains and their dimensions.

Figure 3-3. Photo of box culvert 3 under western perimeter road which channels the runoff from the Mammee gully.

Figure 3-4. Pictures shows 36" pipe culvert 2 which channels runoff into the off site into the Mammee gully.

As stated previously, the Mammee gully crosses the Old Harbour main road via a box culvert, 6.1m high and 15 m wide. Please see Figure 3-5

Figure 3-5. Box Culvert under Old Harbour main road.

It was important to calculate the capacity of this gully to see if the gully would be able to handle the additional flows expected after the operation of the quarry has begun.

Hydrologic analysis of the Mammee gully and surrounding catchment which has an approximate area of 442 hectares, (please see Figure 3-6) was conducted for the 50 year return period (455 mm/24hrs) as specified by the NWA guidelines mentioned previously for flood control. The results of this analysis predicted that a peak flow of 54 cubic metres per second would be expected.

The hydrologic analysis of this channel indicates it is able to accommodate the peak flow expected from the 50 year event. The culvert (box culvert 3) is restrictive to this flow and is therefore undersized. This finding is corroborated with the anecdotal data collected.

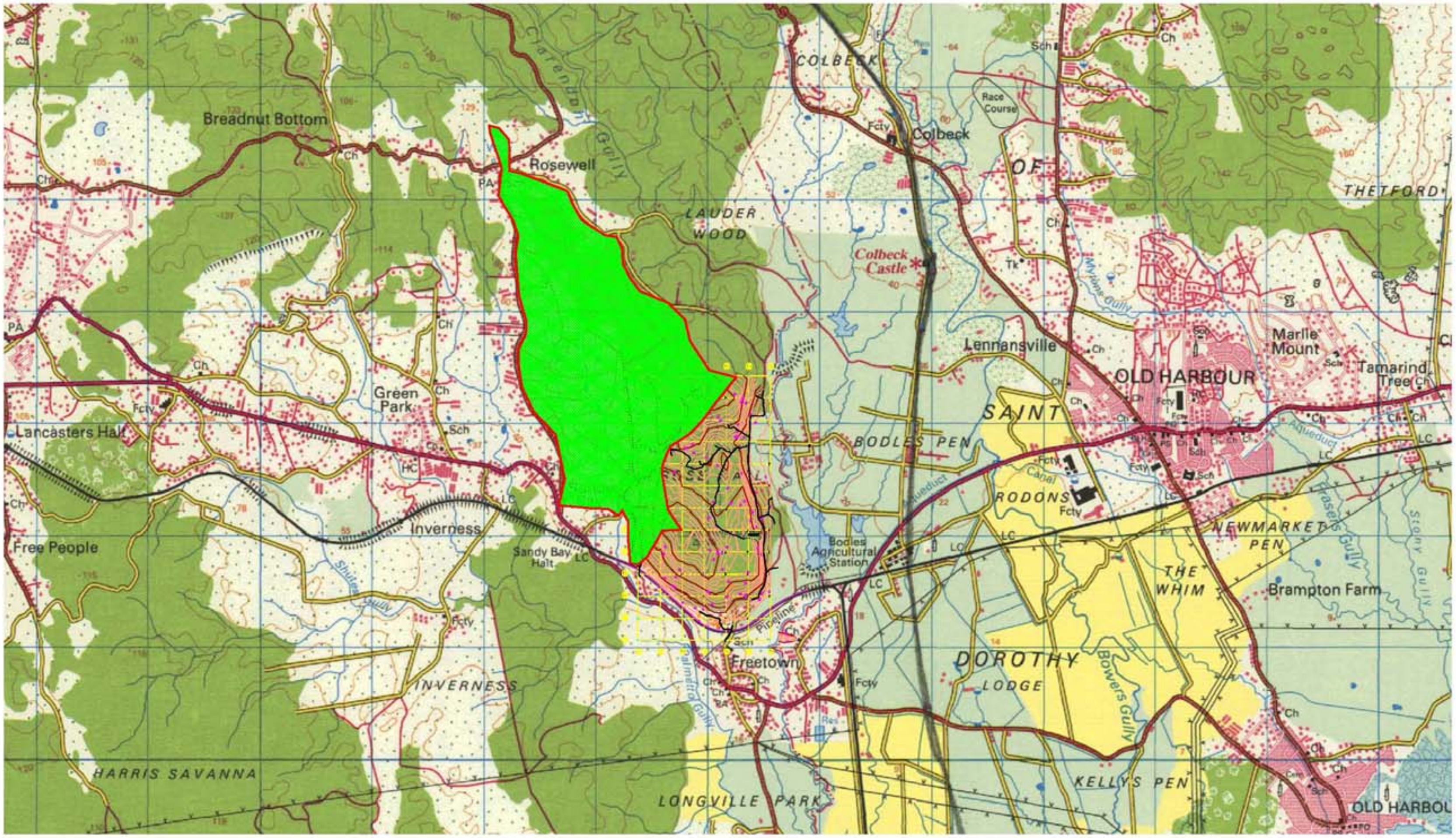

Figure 3-6. Catchment associated with Mammee Gully

3.2.1 Limitations of Hydrologic Analysis

It is important to note that there was insufficient topographic information with respect to the Clarendon gully and the Mammee Gully. For this reason, the true elevation of the invert of the gully was not known. Given this limitation, the contour data obtained from the site specific survey and the 50 000 map series was used in the analysis.

The peak flow predicted from our hydrologic analysis may not be very accurate as scrutiny of the 50 000 map for the area showed several depressions upstream which during rainfall events, act as ponds. This would significantly decrease the peak flow downstream and so may explain why flooding is not experienced at the site contrary to the topography.

4 Proposed Drainage Infrastructure

4.1 Drain Sizing Guidelines

The drainage for the project was designed according to specific guidelines set out in the Ministry of Transport and Works Guidelines for Drainage review of Subdivisions and Development Applications (May 2007). Some of these guidelines are as follows:

- The return period to be used for flood control is 1 in 50 year.
- The freeboard in all drains must be at least 25% of the depth of channel

4.2 Hydrology

The hydrology was analyzed using the Natural Resources Conservation Service (NRCS) Method for generating peak flow. This method incorporates selecting a single curve number to describe the runoff land and soil conditions.

For the analysis a type III distribution curve was used.

4.2.1 <u>SCS Method</u>

SCS method is an empirical model for rainfall runoffs which is based on the potential for the soil to absorb a certain amount of moisture. On the basis of field observations, this potential storage S (millimeters or inches) was related to a 'curve number' *CN* which is a characteristic of the soil type, land use and the initial degree of saturation known as the antecedent moisture condition.

4.2.2 <u>Curve numbers</u>

The curve number used in the SCS method was extracted from the recommended set of values given in the 'Stormwater Collection Systems Design Handbook' – written by Larry W. Mays, PH.D., PE., P.H.

The selected curve numbers were 65 for the existing conditions (ie. thick ground cover) and 87 for the post construction given the type of soil and the observed land use corroborated by that stated in the "Soil and Land-Use Surveys" for Clarendon.

4.2.3 Runoff

The topography of the site shows the land is drained toward the boundaries and ultimately south via overland sheet flow and shallow concentrated flows to the existing gullies and roads.

When the quarry is in full operation the runoff will increase because the vegetation has been removed. Table 4 1 shows the estimated pre development and post development runoffs expected from the catchments during a 50 year storm event. It shows the flows are expected to increase from seven to ten percent.

Table 4-1

	Peak Runoff		
	Pre- Quarry	Post Quarry	Increase
Western	8.04	8.59	7%
Southern	6.03	6.6	9%
Eastern	11.15	12.21	10%

Table 4 2 shows the runoffs in the two gullies and how they will be impacted by the developments. The flows will increase by one (1) percent in the Mammee Gully and 0.4 percent in the Clarendon Gully.

Table 4-2

	Peak Runoff		
	Pre- Quarry	Post Quarry	Increase
Mammee Gully	54	54.55	1.0%
Clarendon Gully	450	451.63	0.4%

4.3 Hydraulics

4.3.1 Methodology

The hydraulics was approached using a steady state analysis. The hydraulics was programmed using the Manning's Equation for the design of an open channel (v-drain), a box drain and drain pipes.

The Manning's equation is one of the most commonly used equations governing open channel flow. The Manning's equation is an empirical equation that applies to uniform flow in open channels and is a function of the channel velocity, flow area and channel slope.

$$Q = VA = \left(\frac{1.49}{n}\right) AR^{\frac{2}{3}}\sqrt{S} \quad [U.S.]$$

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}}\sqrt{S} \quad [SI]$$

Where:

Q = Flow Rate, (ft^3/s)
v = Velocity, (ft/s)
A = Flow Area, (ft^2)
n = Manning's Roughness Coefficient
R = Hydraulic Radius, (ft)
S = Channel Slope, (ft/ft)

4.3.2 Drains

The proposed plan is to channel the runoff along existing drainage paths to the existing gullies - Mammee Gully and Clarendon Gully.

4.3.2.1 Eastern Catchment

Table 4 3 outlines the summary of the hydraulic calculations, estimating the drain required to convey the flows to the Clarendon Gully.

Table 4-3 Required terminal drain for eastern catchment

Trapezoidal- Channel	**Values**	**Units**
Slope	0.468%	
Mannings Coefficient	0.035	
Side slope	1.5	
Width of channel (at top)	5.90	m
Flow Depth	1.50	m
Depth + freeboard	1.88	m
R	1.0	m
P	5.68	m
A	5.79	m^2
Velocity	1.98	m/s
Flow	**11.46**	**m^3/sec**
Tt	**0.13**	**hours**

4.3.2.2 Southern Catchment

Table 4 3 outlines the summary of the hydraulic calculations, estimating the drain required to convey the flows to the Mammee Gully.

Table 4-4 Required terminal drain for southern catchment

Trapezoidal- Channel	Values	Units
Slope	0.468%	
Mannings Coefficient	0.035	
Side slope	1.5	
Width of channel (at top)	4.90	m
Flow Depth	1.50	m
Depth + freeboard	1.88	m
R	0.8	m
P	4.68	m
A	3.91	m^2
Velocity	1.73	m/s
Flow	**6.79**	**m^3/sec**
Tt	**0.14**	**hours**

4.3.2.3 Western Catchment

The Western catchment requires two drains into the Mammee Gully

Table 4-5 Required drain 1 in the western catchment

Trapezoidal- Channel	Values	Units
Slope	0.468%	
Mannings Coefficient	0.035	
Side slope	1.5	
Width of channel (at top)	4.20	m
Flow Depth	1.20	m
Depth + freeboard	1.50	m
R	0.7	m
P	4.03	m
A	2.93	m^2
Velocity	1.58	m/s
Flow	**4.62**	**m^3/sec**
Tt	**0.04**	**hours**

Table 4-6 Required drain 2 in the western catchment to the Mammee drain

Trapezoidal- Channel	Values	Units
Slope	0.468%	
Mannings Coefficient	0.035	
Side slope	1.5	
Width of channel (at top)	4.00	m
Flow Depth	1.20	m
Depth + freeboard	1.50	m
R	0.7	m
P	3.83	m
A	2.63	m^2
Velocity	1.52	m/s
Flow	**3.99**	**m^3/sec**
Tt	**0.03**	**hours**

5 Conclusions and Recommendations

5.1 Conclusions

The following could be concluded from the analysis conducted to date:

- The Catchments for site are primarily bounded by the natural topography in the area. The estimated 50 year peak flow from these catchments are expected to increase during the operation of the quarry as shown in Table 4 1
- The increases in flows are not expected to significantly affect the flows in the Clarendon and Mammee as they Gullies as shown in Table 4 2
- There are no historical flood events on the site excepting at a box culvert 3 which channels the Mammee Gully flow under an existing local road. This however is said to be a rare occurrence.

5.2 Recommendations

The following are our recommendations based on the analysis and design conducted:

- The existing drains which lead to the western Mammee Gully should be upgraded and utilised to convey the flows from the site as they are doing presently.
- The operation of the quarry should be done in phases starting from the north to the south this will minimise the added capacities required in the existing drains
- All drains from the site to the Gullies must be retrofitted with check dams to reduce the discharge velocities and sediments from the site.
- Check dams must be cleaned at minimum, after each major rainfall event to ensure it stays clean and feasible.