# Second Quarterly Report on the Sediment Budget Study of the Rio Grande Watershed Portland Parish, Jamaica

# Ridge to Reef Watershed Project

USAID Contract No. 532-C-00-00-00235-00

## Second Quarterly Report on the Sediment Budget Study of the Rio Grande Watershed Portland Parish, Jamaica

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Prepared for the:

Government of Jamaica
National Environment and Planning Agency

And the

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# Background

This study, for which this document is the second quarterly report, is for a one-year investigation of the Rio Grande fluvial system and the beach system at St. Margaret's Bay in order to make a preliminary determination of the sedimentary budgets of these systems. The study was commissioned by ARD as a part of the Ridge to Reef Watershed Project.

### Purpose of the Study

The purpose of the study is to investigate the various natural processes that occur within the Rio Grande watershed in order to estimate the rate of sediment production in the watershed and to measure the rate at which it moves through the system to the sea. Estimates are being made of the amount of sediment generated in the watershed through weathering and down slope processes and the amount lost to the sea on an annual basis. Storage of sediment in the system is being evaluated, especially in relation to the amounts of material removed by mining activities. The parallel study of the St. Margaret's Bay beach system is designed to identify the processes that contribute to the delivery of sediment from the Rio Grande to the beaches and removal of sediment from the beaches. It also aims to identify the various sediment sources and sinks for the beach and estimate the size of the sources and probable rates of replenishment of the source material.

### Expected Impact on Watershed Management and Policy

The study will enable estimates to be made of sand and gravel reserves in the riverbed and the expected rate of replenishment; estimates to be made of sand and gravel supplies to the beach and removal from the beach. These findings can then be assessed in relation to the mining activities and to the beach erosion that have been taking place. The results of the assessments can be applied to the management policy for the watershed, in particular in setting out limits for sand and gravel removal from the watershed, in particular in setting out limits for sand and gravel removal from the riverbed. In the Bay, the results will enable decisions to be made regarding the feasibility of such questions as using beach nourishment versus hard protection of the shoreline.

# Rio Grande Valley, Eastern Jamaica

## A1. Introduction

In the ongoing effort to create a sedimentation budget for the Rio Grande River Drainage Basin, the tasks completed during the second quarter of the project are listed and discussed below. In addition to the project update, factors hindering the progress thus far are also mentioned.

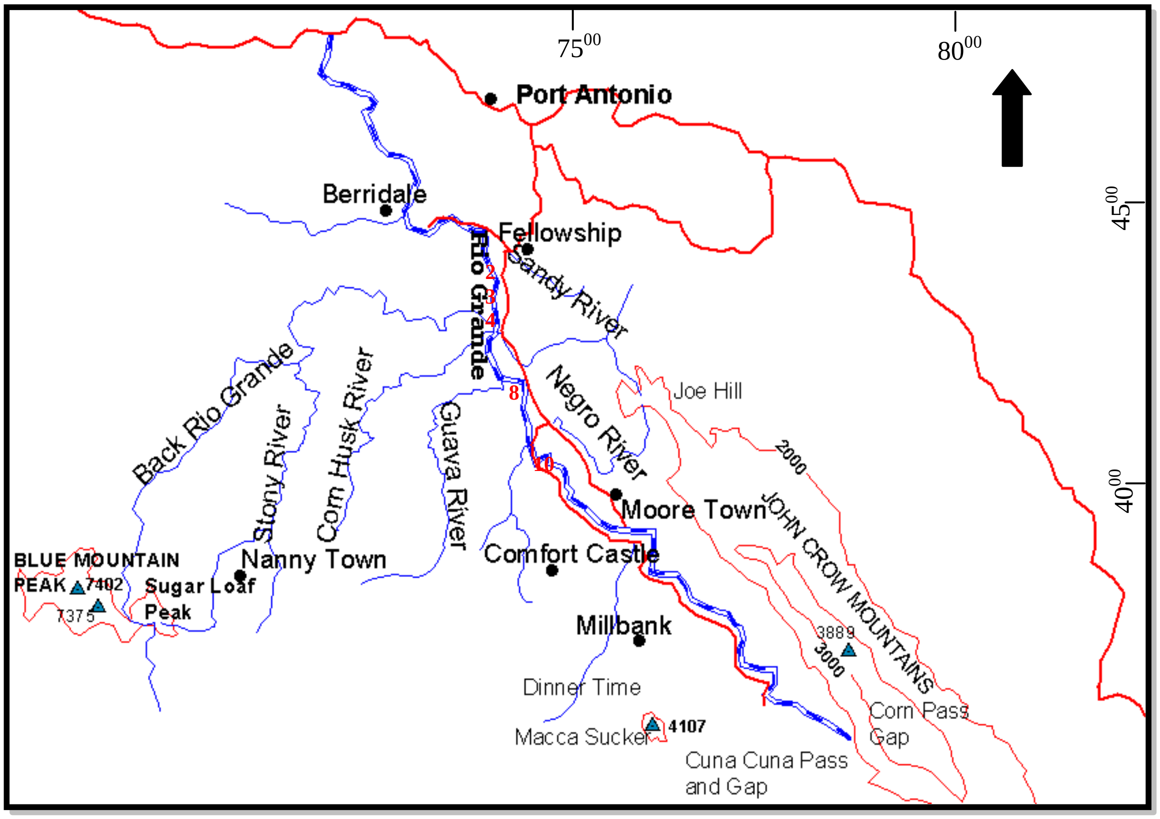



**Figure 1** Locality map of study area showing major confluences involved in the project. Numbers on map concur with cross-section numbers.

## A2. Work Completed

The primary tasks in the second tri-monthly period have been completed as follows:

- The main river channel was re-surveyed at the ten selected cross-sections.
- An additional cross-section was surveyed downstream of Berridale.
- The second phase of river channel-bed and -bar armour sampling by standard Inman Count was completed at the ten channel cross-sections. The bed armour was also analyzed at the newly surveyed cross-section.
- Further bulk samples of the sub-armour sands and gravels were collected from point-bars and braid-bars at the channel cross-sections. These samples were then oven-dried and subsequently sieved using a nest of standard test-sieves for grain-size analysis.

- ✍ Landslide inventory maps have been prepared and digitized covering a large portion of the drainage basin, and classified into recent and older slope failures.

- ✍ Fortnightly suspended sediment sampling at Fellowship Bridge and sampling during floods continued throughout the tri-monthly study period.

It was hoped to complete a geophysical survey of the main Rio Grande floodplain to establish the extent of sediment storage in the main sediment sink of the valley, but this has been postponed until September. A more detailed breakdown of the work completed in the second tri-monthly period is given below.

### *A2.1 Sediment Storage and Transport Studies*

#### A2.1.1 River Channel Morphology

River channel cross-sections were re-surveyed using a Leica T100 electronic theodolite and graduated staff, which can be read to an accuracy of 0.0025m. A total of ten river cross-sections were re-surveyed from the selected localities within the middle, alluvial, course of the Rio Grande River between Fellowship Bridge and Alligator Church Bridge (figure 1), in the main sediment storage sink of the river.

A sample of the channel cross-sections are illustrated in figures 2 and 3, which have a x5 vertical exaggeration to accentuate the point-bars and braid-bars within the river.
Comparison with the cross-sections completed during the first quarter shows that some sections have experienced significant channel bed scour, in response to flood events in May and June, while lateral bar erosion and formation of a flood-chute is evident at the Back Rio Grande cross-section. This bed scouring suggests a high degree of bedload mobility and downstream sediment transport during flood pulses.

An additional cross-section was surveyed downstream of the Foxes River and Sandy River confluences to the north of Berridale. This was done in order to geographically extend the river channel change survey, and to monitor sediment influx from the aforementioned tributaries and sediment dynamics downstream of sand and gravel mining.

The eleven cross-sections provide a survey for continued monitoring and estimation of channel stability, potential in-stream erosion from channel bed (river incision) and/or channel bank sources, or in-stream sediment storage through channel aggradation at the selected localities.

**Selected River Cross-Sections that Showed Distinctive Change in Profile**

**Figure 2** Cross-Section #3- Back Rio Grande Confluence

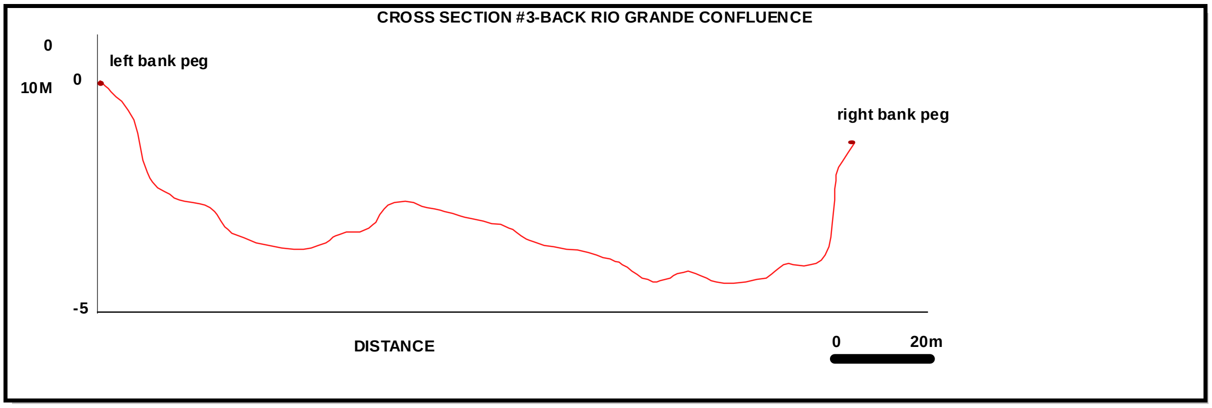
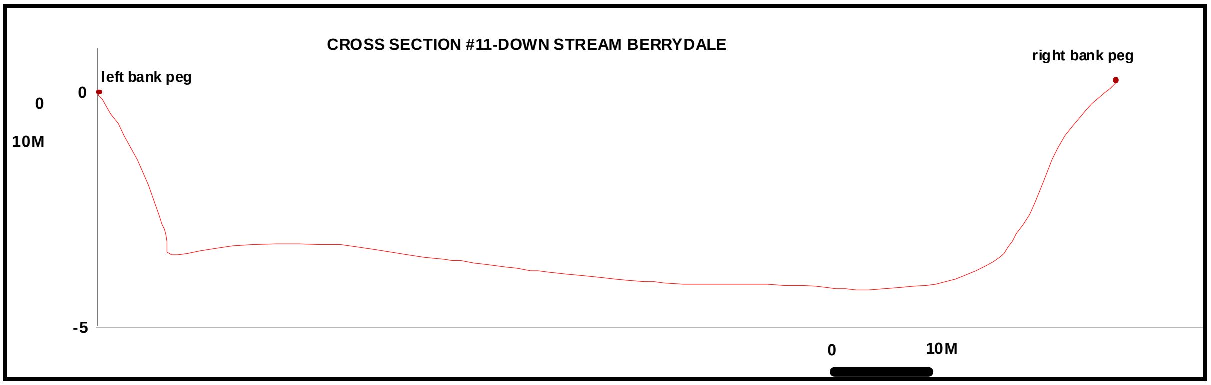



**Figure 3** Cross Section #11 – Down Stream Berrydale




A2.1.2 River Channel Sediments

River sediment sampling was undertaken at the eleven channel cross-section survey sites.

**Armour Sediments**

The granules, pebbles and cobbles armouring the channel bed, point-bars and braid-bars at eleven cross-sections were re-analyzed using standard Inman Counts of the material. Tables 1-11 show the results of the Inman Counts. Initial comparisons with samples collected during the first quarter show that at sites with some bed scour, the bedload coarsened, possibly as a result of selective transport of the finer bedload fraction during floods. Figures 4 to 14 depict cumulative frequency curves for the Inman Counts.

**Tables 1-11** Inman Count Data from Eleven Localities

**Table 1** Cross Section # 1

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -8 | 256 | | 0 | 0 |
| -7.5 | 181.019 | | 0 | 0 |
| 7 | 128 | 4 | 6.25 | 6.25 |
| -6.5 | 90.51 | 8 | 12.5 | 18.75 |
| -6 | 64 | 11 | 17.19 | 35.94 |
| -5.5 | 45.255 | 11 | 17.19 | 53.13 |
| -5 | 32 | 15 | 23.44 | 76.57 |
| -4.5 | 22.627 | 10 | 15.63 | 92.2 |
| -4 | 16 | 1 | 1.56 | 93.76 |
| -3.5 | 11.314 | 1 | 1.56 | 95.32 |
| -3 | 8 | 2 | 3.12 | 98.44 |
| -2.5 | 5.657 | 0 | 0 | 98.44 |
| -2 | 4 | 0 | 0 | 98.44 |
| -1.5 | 2.828 | 0 | 0 | 98.44 |
| -1 | 2 | 0 | 0 | 98.44 |
| < -1.0 | < 2 | 1 | 1.56 | 100 |

**Table 2** Cross Section # 2

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -9 | 512 | 0 | 0 | 0 |
| -8.5 | 362.039 | 1 | 1.64 | 1.64 |
| -8 | 256 | 9 | 14.75 | 16.39 |
| -7.5 | 181.019 | 2 | 3.28 | 19.67 |
| -7 | 128 | 14 | 22.95 | 42.62 |
| -6.5 | 90.51 | 9 | 14.75 | 57.37 |
| 6 | 64 | 9 | 14.75 | 72.12 |
| -5.5 | 45.255 | 5 | 8.2 | 80.32 |
| -5 | 32 | 3 | 4.92 | 85.24 |
| -4.5 | 22.627 | 2 | 3.28 | 88.52 |
| -4 | 16 | 1 | 1.64 | 90.16 |
| -3.5 | 11.314 | 2 | 3.28 | 93.44 |

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -3 | 8 | 2 | 3.28 | 96.72 |
| -2.5 | 5.657 | 0 | 0 | 96.72 |
| -2 | 4 | 1 | 1.64 | 98.36 |
| -1.5 | 2.828 | 0 | 0 | 98.36 |
| < -1 | < 2 | 1 | 1.64 | 100 |

**Table 3** Cross Section # 3

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -10 | 1024 | 0 | 0 | 0 |
| -9.5 | 724.077 | 0 | 0 | 0 |
| -9 | 512 | 0 | 0 | 0 |
| -8.5 | 362.039 | 0 | 0 | 0 |
| -8 | 256 | 5 | 5 | 5 |
| -7.5 | 181.019 | 11 | 11 | 16 |
| -7 | 128 | 9 | 9 | 25 |
| -6.5 | 90.51 | 17 | 17 | 42 |
| 6 | 64 | 18 | 18 | 60 |
| -5.5 | 45.255 | 11 | 11 | 71 |
| -5 | 32 | 10 | 10 | 81 |
| -4.5 | 22.627 | 4 | 4 | 85 |
| -4 | 16 | 5 | 5 | 90 |
| -3.5 | 11.314 | 1 | 1 | 91 |
| -3 | 8 | 6 | 6 | 97 |
| -2.5 | 5.657 | 0 | 0 | 97 |
| -2 | 4 | 0 | 0 | 97 |
| -1.5 | 2.828 | 0 | 0 | 97 |
| < -1 | 2 | 0 | 0 | 97 |
| < -1.0 | < 2 | 3 | 3 | 100 |

**Table 4** Cross Section # 4

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
|  | 512 | 0 | 0 | 0 |
| -8.5 | 362.039 | 1 | 1.37 | 1.37 |
| -8 | 256 | 5 | 6.85 | 8.22 |
| -7.5 | 181.019 | 11 | 15.07 | 23.29 |

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -7 | 128 | 4 | 5.48 | 28.77 |
| -6.5 | 90.51 | 4 | 5.48 | 34.25 |
| 6 | 64 | 10 | 13.7 | 47.95 |
| -5.5 | 45.255 | 14 | 19.18 | 67.13 |
| -5 | 32 | 8 | 10.95 | 78.08 |
| -4.5 | 22.627 | 6 | 8.22 | 86.3 |
| -4 | 16 | 4 | 5.48 | 91.78 |
| -3.5 | 11.314 | 0 | 0 | 91.78 |
| -3 | 8 | 5 | 6.85 | 98.63 |
| -2.5 | 5.657 | 0 | 0 | 98.63 |
| -2 | 4 | 0 | 0 | 98.63 |
| -1.5 | 2.828 | 0 | 0 | 98.63 |
| < -1 | 2 | 0 | 0 | 98.63 |
| < -1.0 | -2 | 1 | 1.37 | 100 |

**Table 5** Cross Section # 5

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -9 | 512 | 0 | 0 | 0 |
| -8.5 | 302.039 | 2 | 3.78 | 3.78 |
| -8 | 256 | 1 | 1.88 | 5.66 |
| -7.5 | 181.019 | 1 | 1.88 | 7.54 |
| -7 | 128 | 2 | 3.78 | 11.32 |
| -6.5 | 90.51 | 1 | 1.88 | 13.2 |
| 6 | 64 | 6 | 11.32 | 24.52 |
| -5.5 | 45.255 | 7 | 13.21 | 37.73 |
| -5 | 32 | 10 | 18.87 | 56.6 |
| -4.5 | 22.627 | 5 | 9.43 | 66.03 |
| -4 | 16 | 3 | 5.66 | 71.69 |
| -3.5 | 11.314 | 1 | 1.88 | 73.57 |
| -3 | 8 | 3 | 5.66 | 79.23 |
| -2.5 | 5.657 | 0 | 0 | 79.23 |
| -2 | 4 | 5 | 9.43 | 88.66 |
| -1.5 | 2.828 | 0 | 0 | 88.66 |
| < -1 | 2 | 4 | 7.56 | 96.22 |

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| < -1.0 | <2 | 2 | 3.78 | 100 |

**Table 6** Cross Section # 6

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -9.5 | 724.077 | 0 | 0 | 0 |
| -9 | 512 | 0 | 0 | 0 |
| -8.5 | 362.039 | 1 | 1.67 | 1.67 |
| -8 | 256 | 3 | 5 | 6.67 |
| -7.5 | 181.019 | 12 | 20 | 26.67 |
| -7 | 128 | 7 | 11.67 | 38.34 |
| -6.5 | 90.51 | 13 | 21.66 | 60 |
| 6 | 64 | 10 | 16.67 | 76.67 |
| -5.5 | 45.255 | 5 | 8.33 | 85.33 |
| -5 | 32 | 5 | 8.33 | 93.33 |
| -4.5 | 22.627 | 4 | 6.67 | 100 |
| -4 | 16 | 0 | 0 | |
| -3.5 | 11.314 | 0 | 0 | |
| -3 | 8 | 0 | 0 | |
| -2.5 | 5.657 | 0 | 0 | |
| -2 | 4 | 0 | 0 | |
| -1.5 | 2.828 | 0 | 0 | |
| < -1 | 2 | 0 | 0 | |
| < -1.0 | <2 | 0 | 0 | |

**Table 7** Cross Section # 7

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -9.5 | 724.077 | 0 | 0 | 0 |
| -9 | 512 | 0 | 0 | 0 |
| -8.5 | 362.039 | 1 | 1.82 | 1.82 |
| -8 | 256 | 8 | 14.54 | 16.36 |
| -7.5 | 181.019 | 19 | 34.54 | 50.9 |
| -7 | 128 | 5 | 9.1 | 60 |
| -6.5 | 90.51 | 8 | 14.54 | 74.54 |
| 6 | 64 | 8 | 14.54 | 89.08 |

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -5.5 | 45.255 | 2 | 3.64 | 92.72 |
| -5 | 32 | 0 | 0 | 92.72 |
| -4.5 | 22.627 | 1 | 1.82 | 94.54 |
| -4 | 16 | 1 | 1.82 | 96.36 |
| -3.5 | 11.314 | 1 | 1.82 | 98.18 |
| -3 | 8 | 0 | 0 | 98.18 |
| -2.5 | 5.657 | 0 | 0 | 98.18 |
| -2 | 4 | 1 | 1.82 | 100 |
| -1.5 | 2.828 | 0 | 0 | |
| < -1 | 2 | 0 | 0 | |
| < -1.0 | <2 | 0 | 0 | |

**Table 8** Cross Section # 8

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -9.5 | 724.077 | 0 | 0 | 0 |
| -9 | 512 | 2 | 2.9 | 2.9 |
| -8.5 | 362.039 | 6 | 8.7 | 11.6 |
| -8 | 256 | 5 | 7.25 | 18.85 |
| -7.5 | 181.019 | 7 | 10.14 | 28.99 |
| -7 | 128 | 5 | 7.25 | 36.24 |
| -6.5 | 90.51 | 7 | 10.14 | 46.38 |
| 6 | 64 | 12 | 17.39 | 63.77 |
| -5.5 | 45.255 | 4 | 5.8 | 69.57 |
| -5 | 32 | 9 | 13.04 | 82.61 |
| -4.5 | 22.627 | 5 | 7.25 | 89.86 |
| -4 | 16 | 1 | 1.45 | 91.31 |
| -3.5 | 11.314 | 0 | 0 | 91.31 |
| -3 | 8 | 1 | 1.45 | 92.76 |
| -2.5 | 5.657 | 0 | 0 | 92.76 |
| -2 | 4 | 1 | 1.45 | 94.21 |
| -1.5 | 2.828 | 0 | 0 | 94.21 |
| < -1 | 2 | 1 | 1.45 | 95.66 |
| < -1.0 | <2 | 3 | 4.34 | 100 |

**Table 9** Cross Section # 9

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -9.5 | 724.077 | 0 | 0 | 0 |
| -9 | 512 | 2 | 2.44 | 2.44 |
| -8.5 | 362.039 | 10 | 12.2 | 14.64 |
| -8 | 256 | 10 | 12.2 | 26.84 |
| -7.5 | 181.019 | 6 | 7.32 | 34.16 |
| -7 | 128 | 6 | 7.32 | 41.48 |
| -6.5 | 90.51 | 7 | 8.54 | 50.02 |
| 6 | 64 | 7 | 8.54 | 58.56 |
| -5.5 | 45.255 | 10 | 12.2 | 70.76 |
| -5 | 32 | 8 | 9.76 | 80.52 |
| -4.5 | 22.627 | 8 | 9.76 | 90.28 |
| -4 | 16 | 2 | 2.44 | 92.72 |
| -3.5 | 11.314 | 1 | 1.21 | 93.93 |
| -3 | 8 | 0 | 0 | 93.93 |
| -2.5 | 5.657 | 3 | 3.65 | 97.58 |
| -2 | 4 | 1 | 1.21 | 98.79 |
| -1.5 | 2.828 | 0 | 0 | 98.79 |
| < -1 | 2 | 0 | 0 | 98.79 |
| < -1.0 | <2 | 1 | 1.21 | 100 |

**Table 10** Cross Section # 10

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -9.5 | 724.077 | 0 | 0 | 0 |
| -9 | 512 | 6 | 10.35 | 10.35 |
| -8.5 | 362.039 | 12 | 20.69 | 31.04 |
| -8 | 256 | 5 | 8.62 | 39.66 |
| -7.5 | 181.019 | 5 | 8.62 | 48.28 |
| -7 | 128 | 6 | 10.35 | 58.63 |
| -6.5 | 90.51 | 10 | 17.24 | 75.87 |
| 6 | 64 | 6 | 10.35 | 86.22 |
| -5.5 | 45.255 | 5 | 8.62 | 94.84 |
| -5 | 32 | 2 | 3.44 | 98.28 |

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -4.5 | 22.627 | 0 | 0 | 98.28 |
| -4 | 16 | 0 | 0 | 98.28 |
| -3.5 | 11.314 | 0 | 0 | 98.28 |
| -3 | 8 | 1 | 1.72 | 100 |
| -2.5 | 5.657 | 0 | 0 | |
| -2 | 4 | 0 | 0 | |
| -1.5 | 2.828 | 0 | 0 | |
| < -1 | 2 | 0 | 0 | |
| < -1.0 | <2 | | | |

**Table 11** Cross Section # 11

| PHI | (mm) | # | % Occurrence | Cumulative % |
|---|---|---|---|---|
| -9 | 512 | 0 | 0 | 0 |
| -8.5 | 362.039 | 0 | 0 | 0 |
| -8 | 256 | 2 | 2.74 | 2.74 |
| -7.5 | 181.019 | 2 | 2.74 | 5.48 |
| -7 | 128 | 6 | 8.22 | 13.7 |
| -6.5 | 90.51 | 7 | 9.59 | 23.29 |
| 6 | 64 | 12 | 16.44 | 39.73 |
| -5.5 | 45.255 | 15 | 20.54 | 60.27 |
| -5 | 32 | 17 | 23.29 | 83.56 |
| -4.5 | 22.627 | 7 | 9.59 | 93.15 |
| -4 | 16 | 2 | 2.74 | 95.89 |
| -3.5 | 11.314 | 1 | 1.37 | 97.26 |
| -3 | 8 | 2 | 2.74 | 100 |
| -2.5 | 5.657 | 0 | 0 | |
| -2 | 4 | 0 | 0 | |
| -1.5 | 2.828 | 0 | 0 | |
| < -1 | 2 | 0 | 0 | |
| < -1.0 | -2 | 0 | 0 | |

**Figures 4 to 14** Cumulative Frequency Curves for Inman Counts

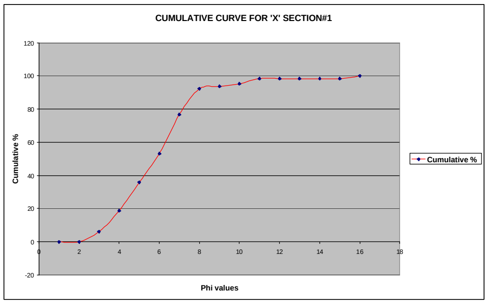



**Fig. 4**

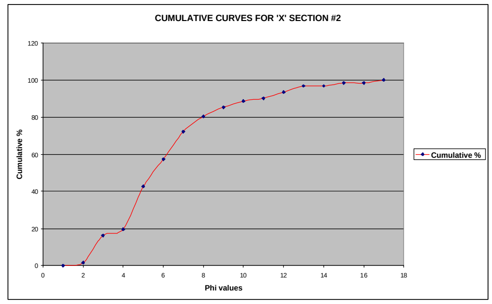



**Fig. 5**

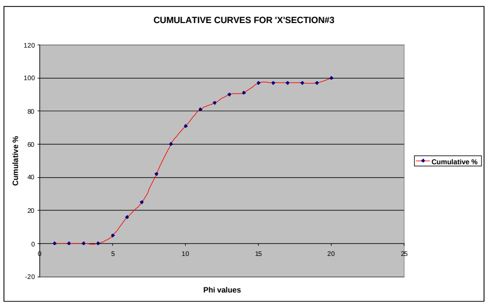



**Fig. 6**

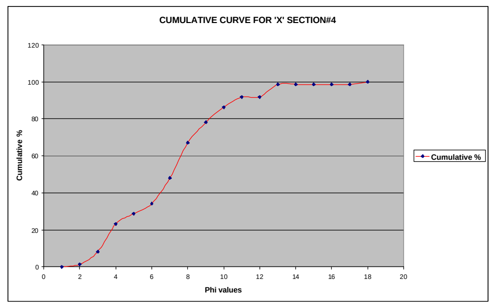



**Fig. 7**

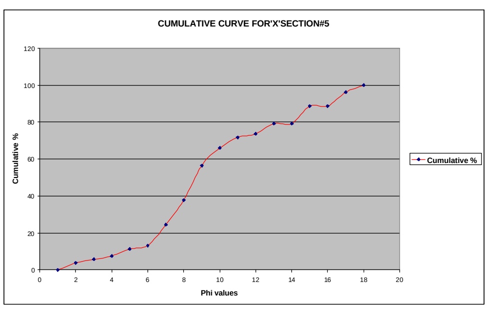



**Fig. 8**

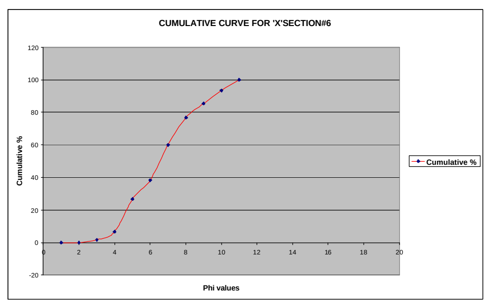



**Fig. 9**

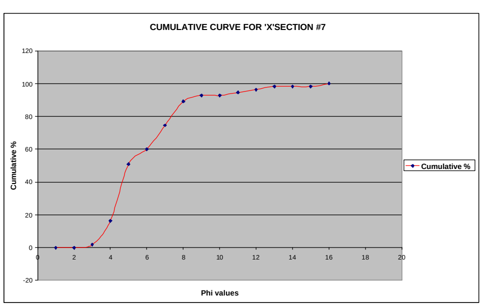



**Fig. 10**

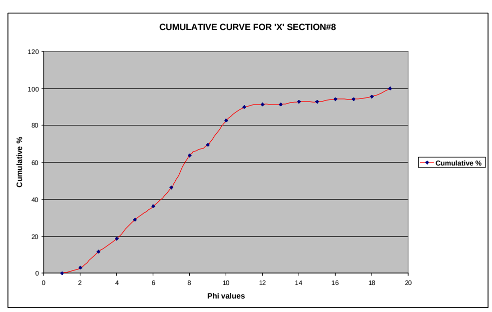



**Fig. 11**

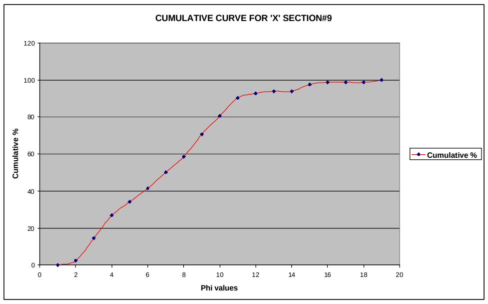



**Fig. 12**

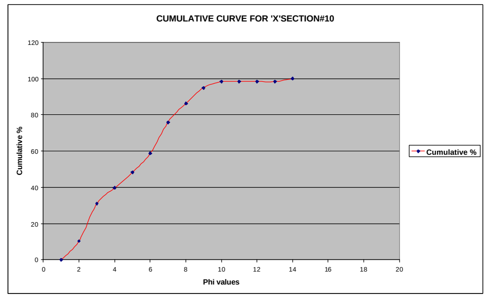



**Fig. 13**

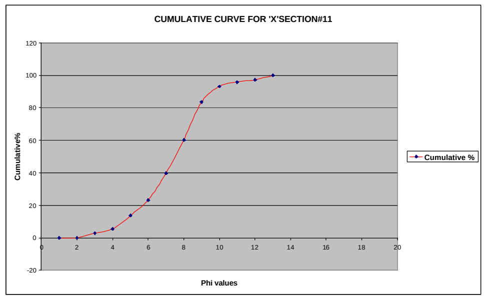



**Fig. 14**

### *Sub-Armour Sediments*

A total of twenty two bulk samples of the sub-armour sands and gravels were collected from the cross-section survey localities, and subsequently analyzed in the laboratory for grain-size determination. Similar to the armour sediments, this data will be used in an assessment of streambed coarsening or fining over the study period, though more importantly, once the bed material grain sizes are known, the mobility of sediments can be estimated through discharge relations and other hydraulic characteristics of the channel.

**Table 12** Grain Size Distribution data from CS2R2 and CS6RB1

| Sieve size (mm) | CS2R2 | | | | CS6RB1 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 30.12 | -4.56 | 0 | 2.96 | 0 | -4.56 | 0 | 0 |
| 12.5 | 142.23 | -3.56 | 2.96 | 13.98 | 86.29 | -3.56 | 0 | 14.46 |
| 9.5 | 55.3 | -3.25 | 16.94 | 5.43 | 69.72 | -3.25 | 14.46 | 11.68 |
| 6.3 | 113.76 | -2.575 | 22.37 | 11.18 | 90.9 | -2.575 | 26.14 | 15.23 |
| 4.75 | 92.43 | -2.25 | 33.55 | 9.08 | 63.82 | -2.25 | 41.37 | 10.7 |
| 4 | 84.81 | -2 | 42.63 | 8.34 | 32.47 | -2 | 52.07 | 5.44 |
| 3.35 | 84.06 | -1.675 | 50.97 | 8.26 | 31.78 | -1.675 | 57.51 | 5.33 |
| 2 | 119.02 | -1 | 59.23 | 11.7 | 63.08 | -1 | 62.84 | 10.57 |
| 1.4 | 47.41 | -0.5 | 70.93 | 4.66 | 37.92 | -0.5 | 73.41 | 6.35 |
| 1 | 20.58 | 0 | 75.59 | 2.02 | 17.81 | 0 | 79.76 | 2.98 |
| 0.71 | 29.04 | 0.5 | 77.61 | 2.85 | 19.65 | 0.5 | 82.74 | 3.29 |

| Sieve size (mm) | CS2R2 | | | | CS6RB1 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 0.5 | 51.47 | 1 | 80.46 | 5.06 | 20.02 | 1 | 86.03 | 3.35 |
| 0.25 | 114.01 | 1.5 | 85.52 | 11.21 | 33.37 | 1.5 | 89.38 | 5.59 |
| 0.125 | 23.97 | 2.25 | 96.73 | 2.35 | 18.07 | 2.25 | 94.97 | 3.02 |
| 0.063 | 6.11 | 4 | 99.08 | 0.6 | 7.68 | 4 | 97.99 | 1.28 |
| <.063 | 2.56 | >4 | 99.68 | 0.25 | 4.14 | >4 | 99.27 | 0.69 |
| | 1016.88 | | 99.93 | 99.93 | 596.72 | | 99.96 | 99.96 |

**Table 13** Grain Size Distribution data from CS4L2 and CS11LB1

| Sieve size (mm) | CS4L2 | | | | CS11LB1 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 0 | -4.56 | 0 | 0 | 0 | -4.56 | 0 | 0 |
| 12.5 | 77.29 | -3.56 | 0 | 10.62 | 88.79 | -3.56 | 0 | 10.71 |
| 9.5 | 66.97 | -3.25 | 10.62 | 9.2 | 82.29 | -3.25 | 10.71 | 9.93 |
| 6.3 | 92.89 | -2.575 | 19.82 | 12.76 | 91.6 | -2.575 | 20.64 | 11.05 |
| 4.75 | 58.97 | -2.25 | 32.58 | 8.1 | 64.05 | -2.25 | 31.69 | 7.73 |
| 4 | 32.89 | -2 | 40.68 | 4.52 | 39.52 | -2 | 39.42 | 4.77 |
| 3.35 | 39.99 | -1.675 | 45.2 | 5.49 | 38.75 | -1.675 | 44.19 | 4.68 |
| 2 | 86.96 | -1 | 50.69 | 11.94 | 99.45 | -1 | 48.87 | 12 |
| 1.4 | 62.22 | -0.5 | 62.63 | 8.54 | 76.68 | -0.5 | 60.87 | 9.26 |
| 1 | 38.8 | 0 | 71.17 | 5.33 | 52.41 | 0 | 70.13 | 6.33 |
| 0.71 | 38.53 | 0.5 | 76.5 | 5.29 | 82.39 | 0.5 | 76.46 | 9.94 |
| 0.5 | 42.38 | 1 | 81.79 | 5.82 | 71.26 | 1 | 86.4 | 8.6 |
| 0.25 | 59.7 | 1.5 | 87.61 | 8.2 | 35.7 | 1.5 | 95 | 4.3 |
| 0.125 | 20.04 | 2.25 | 95.81 | 2.75 | 3.9 | 2.25 | 99.3 | 0.47 |
| 0.063 | 8.75 | 4 | 98.56 | 1.2 | 1.39 | 4 | 99.77 | 0.17 |
| <.063 | 1.43 | >4 | 99.76 | 0.19 | 0.31 | >4 | 99.94 | 0.03 |
| | 727.81 | | 99.95 | 99.95 | 828.49 | | 99.97 | 99.97 |

**Table 14** Grain Size Distribution data from CS7R2 and CS1RBL

| Sieve size (mm) | CS7R2 | | | | CS1RBL | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 0 | -4.56 | 0 | 0 | 0 | -4.56 | 0 | 0 |
| 12.5 | 2.96 | -3.56 | 0 | 0.44 | 162.33 | -3.56 | 0 | 23.86 |
| 9.5 | 6.18 | -3.25 | 0.44 | 0.9 | 89.8 | -3.25 | 23.86 | 13.19 |

| Sieve size (mm) | CS7R2 | | | | CS1RBL | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 6.3 | 64.91 | -2.575 | 1.34 | 9.54 | 94.34 | -2.575 | 37.05 | 13.86 |
| 4.75 | 68.48 | -2.25 | 10.88 | 10.07 | 63.98 | -2.25 | 50.91 | 9.4 |
| 4 | 63.77 | -2 | 20.95 | 9.38 | 44.35 | -2 | 60.31 | 6.52 |
| 3.35 | 73.5 | -1.675 | 30.33 | 10.81 | 49.53 | -1.675 | 66.83 | 7.28 |
| 2 | 189.26 | -1 | 41.13 | 27.84 | 70.26 | -1 | 74.11 | 10.32 |
| 1.4 | 115.46 | -0.5 | 68.98 | 16.98 | 26.1 | -0.5 | 84.43 | 3.84 |
| 1 | 45.47 | 0 | 85.96 | 6.69 | 14.9 | 0 | 88.27 | 2.19 |
| 0.71 | 29.42 | 0.5 | 92.65 | 4.32 | 19.16 | 0.5 | 90.46 | 2.82 |
| 0.5 | 10.66 | 1 | 96.97 | 1.57 | 15.67 | 1 | 93.28 | 2.3 |
| 0.25 | 4.73 | 1.5 | 98.54 | 0.69 | 14.09 | 1.5 | 95.58 | 2.07 |
| 0.125 | 2.48 | 2.25 | 99.23 | 0.36 | 8.99 | 2.25 | 97.65 | 1.32 |
| 0.063 | 2.4 | 4 | 99.59 | 0.35 | 6.36 | 4 | 98.97 | 0.93 |
| <.063 | 0.19 | >4 | 99.94 | 0.03 | 0.57 | >4 | 99.9 | 0 |
| | 679.87 | | 99.97 | 99.97 | 680.43 | | 99.9 | 99.9 |

**Table 15** Grain Size Distribution data from CS3LB3 and CS8RB2

| Sieve size (mm) | CS3LB3 | | | | CS8RB2 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 0 | -4.56 | 0 | 0 | 0 | -4.56 | 0 | 0 |
| 12.5 | 239.34 | -3.56 | 0 | 22.23 | 98.3 | -3.56 | 0 | 14.96 |
| 9.5 | 141.92 | -3.25 | 22.23 | 13.18 | 31.09 | -3.25 | 14.96 | 4.73 |
| 6.3 | 168.8 | -2.575 | 35.41 | 15.68 | 43.34 | -2.575 | 19.69 | 6.59 |
| 4.75 | 96.52 | -2.25 | 51.09 | 8.96 | 23.59 | -2.25 | 26.28 | 3.59 |
| 4 | 40.95 | -2 | 60.05 | 3.8 | 23.31 | -2 | 29.87 | 3.55 |
| 3.35 | 40.25 | -1.675 | 63.85 | 3.73 | 20.82 | -1.675 | 33.42 | 3.17 |
| 2 | 64.23 | -1 | 67.58 | 5.97 | 70.55 | -1 | 36.59 | 10.74 |
| 1.4 | 38.87 | -0.5 | 73.55 | 3.61 | 83.03 | -0.5 | 47.33 | 12.63 |
| 1 | 24.17 | 0 | 77.16 | 2.24 | 66.48 | 0 | 59.96 | 10.12 |
| 0.71 | 42.99 | 0.5 | 79.4 | 3.99 | 87.15 | 0.5 | 70.08 | 13.26 |
| 0.5 | 73.07 | 1 | 83.39 | 6.79 | 55.48 | 1 | 83.34 | 8.44 |
| 0.25 | 79.22 | 1.5 | 90.18 | 7.36 | 41.04 | 1.5 | 91.78 | 6.24 |
| 0.125 | 19.25 | 2.25 | 97.54 | 1.79 | 9.96 | 2.25 | 98.02 | 1.52 |
| 0.063 | 5.35 | 4 | 99.33 | 0.49 | 2.67 | 4 | 99.54 | 0.41 |
| <.063 | 1.77 | >4 | 99.82 | 0.16 | 0.36 | >4 | 99.95 | 0.05 |

| Sieve size (mm) | CS3LB3 | | | | CS8RB2 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| | 1076.7 | | 99.98 | 99.98 | 657.17 | | 100 | 100 |

**Table 16** Grain Size Distribution data from CS2R1 and CS5R2

| Sieve size (mm) | CS2R1 | | | | CS5R2 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 0 | -4.56 | 0 | 0 | 0 | -4.56 | 0 | 0 |
| 12.5 | 212.91 | -3.56 | 0 | 23.83 | 172.31 | -3.56 | 0 | 28.53 |
| 9.5 | 92.81 | -3.25 | 23.83 | 10.39 | 84.31 | -3.25 | 28.53 | 13.96 |
| 6.3 | 91.54 | -2.575 | 34.22 | 10.25 | 111.64 | -2.575 | 42.49 | 18.48 |
| 4.75 | 51.82 | -2.25 | 44.47 | 5.8 | 55.62 | -2.25 | 60.97 | 9.21 |
| 4 | 28.45 | -2 | 50.27 | 3.18 | 43.7 | -2 | 70.18 | 7.23 |
| 3.35 | 20.42 | -1.675 | 53.45 | 2.29 | 32.52 | -1.675 | 77.41 | 5.38 |
| 2 | 37.43 | -1 | 55.74 | 4.19 | 61.54 | -1 | 82.79 | 10.19 |
| 1.4 | 20.03 | -0.5 | 59.93 | 2.24 | 22.68 | -0.5 | 92.98 | 3.75 |
| 1 | 10.98 | 0 | 62.17 | 1.23 | 6.31 | 0 | 96.73 | 1.04 |
| 0.71 | 18.49 | 0.5 | 63.4 | 2.07 | 3.94 | 0.5 | 97.77 | 0.65 |
| 0.5 | 34.41 | 1 | 65.47 | 3.85 | 2.09 | 1 | 98.42 | 0.35 |
| 0.25 | 145.35 | 1.5 | 69.32 | 16.27 | 0.97 | 1.5 | 98.77 | 0.16 |
| 0.125 | 104.8 | 2.25 | 85.59 | 11.73 | 2.31 | 2.25 | 98.93 | 0.38 |
| 0.063 | 23.32 | 4 | 97.32 | 2.61 | 3.87 | 4 | 99.31 | 0.64 |
| <.063 | 0.54 | >4 | 99.93 | 0.06 | 0.31 | >4 | 99.95 | 0.05 |
| | 893.3 | | 99.99 | 99.99 | 604.12 | | 100 | 100 |

**Table 17** Grain Size Distribution data from CS3LB1 and CS1LB

| Sieve size (mm) | CS3LB1 | | | | CS1LB | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 160.21 | -4.56 | 0 | 14.95 | 0 | -4.56 | 0 | 0 |
| 12.5 | 149.45 | -3.56 | 14.95 | 13.94 | 158.57 | -3.56 | 0 | 23.3 |
| 9.5 | 63.68 | -3.25 | 28.89 | 5.94 | 91.01 | -3.25 | 23.3 | 13.37 |
| 6.3 | 60.89 | -2.575 | 34.83 | 5.68 | 122.32 | -2.575 | 36.67 | 17.97 |
| 4.75 | 26.36 | -2.25 | 40.51 | 2.45 | 45.25 | -2.25 | 54.64 | 6.65 |
| 4 | 18.09 | -2 | 42.96 | 1.69 | 28.96 | -2 | 61.29 | 4.25 |
| 3.35 | 23.66 | -1.675 | 44.65 | 2.2 | 28.93 | -1.675 | 65.54 | 4.25 |
| 2 | 62.84 | -1 | 46.85 | 5.86 | 47.84 | -1 | 69.79 | 7.03 |

| Sieve size (mm) | CS3LB1 | | | | CS1LB | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 1.4 | 79.66 | -0.5 | 52.71 | 7.43 | 35.25 | -0.5 | 76.82 | 5.18 |
| 1 | 78.66 | 0 | 60.14 | 7.34 | 22.76 | 0 | 82 | 3.34 |
| 0.71 | 143.2 | 0.5 | 67.48 | 13.36 | 43.5 | 0.5 | 85.34 | 6.39 |
| 0.5 | 122.01 | 1 | 80.84 | 11.38 | 36.67 | 1 | 91.73 | 5.38 |
| 0.25 | 71.85 | 1.5 | 92.22 | 6.7 | 15.48 | 1.5 | 97.11 | 2.27 |
| 0.125 | 8.11 | 2.25 | 98.92 | 0.76 | 2.54 | 2.25 | 99.38 | 0.37 |
| 0.063 | 2.57 | 4 | 99.68 | 0.02 | 1.41 | 4 | 99.75 | 0.21 |
| <.063 | 0.5 | >4 | 99.7 | 0.05 | 0.13 | >4 | 99.96 | 0.02 |
| | 1071.74 | | 99.75 | 99.75 | 680.62 | | 99.98 | 99.98 |

**Table 18** Grain Size Distribution data from CS4R1 and CS3LB2

| Sieve size (mm) | CS4R1 | | | | CS3LB2 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 0 | -4.56 | 0 | 0 | 35.41 | -4.56 | 0 | 4.89 |
| 12.5 | 149.69 | -3.56 | 0 | 20.75 | 71.02 | -3.56 | 4.89 | 9.82 |
| 9.5 | 80.72 | -3.25 | 20.75 | 11.19 | 39.58 | -3.25 | 14.71 | 5.47 |
| 6.3 | 90.19 | -2.575 | 31.94 | 12.5 | 56.62 | -2.575 | 20.18 | 7.83 |
| 4.75 | 61.25 | -2.25 | 44.44 | 8.49 | 35.26 | -2.25 | 28.01 | 4.87 |
| 4 | 27.73 | -2 | 52.93 | 3.84 | 21.9 | -2 | 32.88 | 3.03 |
| 3.35 | 30.37 | -1.675 | 56.77 | 4.21 | 29.1 | -1.675 | 35.91 | 4.02 |
| 2 | 58.09 | -1 | 60.98 | 8.05 | 85.9 | -1 | 39.93 | 11.87 |
| 1.4 | 41.34 | -0.5 | 69.03 | 5.73 | 91.54 | -0.5 | 51.8 | 12.65 |
| 1 | 31.42 | 0 | 74.76 | 4.35 | 62.65 | 0 | 64.45 | 8.66 |
| 0.71 | 51.33 | 0.5 | 79.11 | 7.11 | 87.74 | 0.5 | 73.11 | 12.13 |
| 0.5 | 50.15 | 1 | 86.22 | 6.95 | 67.99 | 1 | 85.24 | 9.4 |
| 0.25 | 35.55 | 1.5 | 93.17 | 4.93 | 30.55 | 1.5 | 94.64 | 4.22 |
| 0.125 | 7.22 | 2.25 | 98.1 | 1 | 5.79 | 2.25 | 98.86 | 0.8 |
| 0.063 | 5.86 | 4 | 99.1 | 0.81 | 2.32 | 4 | 99.66 | 0.32 |
| <.063 | 0.57 | >4 | 99.91 | 0.08 | 0.15 | >4 | 99.98 | 0.02 |
| | 721.48 | | 99.99 | 99.99 | 723.52 | | 100 | 100 |

**Table 19** Grain Size Distribution data from CS4L1 and CS5R1

| Sieve size (mm) | CS4L1 | | | | CS5R1 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 0 | -4.56 | 0 | 0 | 0 | -4.56 | 0 | 0 |
| 12.5 | 118.32 | -3.56 | 0 | 19.44 | 137.06 | -3.56 | 0 | 15.94 |
| 9.5 | 73.46 | -3.25 | 19.44 | 12.07 | 75.72 | -3.25 | 15.94 | 8.81 |
| 6.3 | 73.51 | -2.575 | 31.51 | 12.08 | 124.35 | -2.575 | 24.75 | 14.47 |
| 4.75 | 27.6 | -2.25 | 43.59 | 4.53 | 79.69 | -2.25 | 39.22 | 9.27 |
| 4 | 21.52 | -2 | 48.12 | 3.54 | 51.58 | -2 | 48.49 | 6 |
| 3.35 | 21.65 | -1.675 | 51.66 | 3.56 | 55.52 | -1.675 | 54.49 | 6.42 |
| 2 | 41.45 | -1 | 55.22 | 6.81 | 110.72 | -1 | 60.91 | 12.88 |
| 1.4 | 34.2 | -0.5 | 62.03 | 5.62 | 54.78 | -0.5 | 73.79 | 6.37 |
| 1 | 27.82 | 0 | 67.65 | 4.57 | 23.85 | 0 | 80.16 | 2.77 |
| 0.71 | 46.09 | 0.5 | 72.22 | 7.57 | 29.71 | 0.5 | 82.93 | 3.46 |
| 0.5 | 50.98 | 1 | 79.79 | 8.38 | 45.57 | 1 | 86.39 | 5.3 |
| 0.25 | 50.92 | 1.5 | 88.17 | 8.37 | 46.57 | 1.5 | 91.69 | 5.42 |
| 0.125 | 16.6 | 2.25 | 96.54 | 2.72 | 18.74 | 2.25 | 97.11 | 2.18 |
| 0.063 | 4.36 | 4 | 99.26 | 0.71 | 5.57 | 4 | 99.29 | 0.65 |
| <.063 | 0.2 | >4 | 99.97 | 0.03 | 0.18 | >4 | 99.94 | 0.02 |
| | 608.68 | | 100 | 100 | 859.61 | | 99.96 | 99.96 |

**Table 20** Grain Size Distribution data from CS1RBR and CS9R1

| Sieve size (mm) | CS1RBR | | | | CS9R1 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 0 | -4.56 | 0 | 0 | 0 | -4.56 | 0 | 0 |
| 12.5 | 140.21 | -3.56 | 0 | 17.42 | 38.45 | -3.56 | 0 | 5.73 |
| 9.5 | 100.5 | -3.25 | 17.42 | 12.49 | 28.73 | -3.25 | 5.73 | 4.28 |
| 6.3 | 102.59 | -2.575 | 29.91 | 12.75 | 77.99 | -2.575 | 10.01 | 11.61 |
| 4.75 | 59.79 | -2.25 | 42.66 | 7.43 | 71.38 | -2.25 | 21.62 | 10.63 |
| 4 | 36.41 | -2 | 50.09 | 4.52 | 41.8 | -2 | 32.25 | 6.23 |
| 3.35 | 39.96 | -1.675 | 54.61 | 4.96 | 53.77 | -1.675 | 38.48 | 8.01 |
| 2 | 106.93 | -1 | 59.57 | 13.29 | 130.16 | -1 | 46.49 | 19.39 |
| 1.4 | 76.92 | -0.5 | 72.86 | 9.56 | 86.18 | -0.5 | 65.88 | 12.83 |
| 1 | 38.41 | 0 | 82.42 | 4.77 | 42.34 | 0 | 78.71 | 6.31 |
| 0.71 | 41.58 | 0.5 | 87.19 | 5.17 | 41.02 | 0.5 | 85.02 | 6.11 |

| Sieve size (mm) | CS1RBR | | | | CS9R1 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 0.5 | 32.58 | 1 | 92.36 | 4.04 | 26.82 | 1 | 91.13 | 3.99 |
| 0.25 | 16.5 | 1.5 | 96.4 | 2.05 | 21.24 | 1.5 | 95.12 | 3.16 |
| 0.125 | 9.73 | 2.25 | 98.45 | 1.21 | 8.37 | 2.25 | 98.28 | 1.25 |
| 0.063 | 2.72 | 4 | 99.66 | 0.34 | 3.14 | 4 | 99.53 | 0.47 |
| <.063 | 0.04 | >4 | 100 | 0 | 0.04 | >4 | 100 | 0 |
| | 804.87 | | 100 | 100 | 671.43 | | 100 | 100 |

**Table 21** Grain Size Distribution data from CS10RB1 and CS11LB2

| Sieve size (mm) | CS10RB1 | | | | CS11LB2 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 0 | -4.56 | 0 | 0 | 0 | -4.56 | 0 | 0 |
| 12.5 | 56.27 | -3.56 | 0 | 9.87 | 103.2 | -3.56 | 0 | 15.12 |
| 9.5 | 63.74 | -3.25 | 9.87 | 11.18 | 81.98 | -3.25 | 15.12 | 12.01 |
| 6.3 | 141.48 | -2.575 | 22.05 | 24.82 | 70.71 | -2.575 | 27.13 | 10.36 |
| 4.75 | 74.17 | -2.25 | 45.87 | 13.01 | 52.78 | -2.25 | 37.49 | 7.73 |
| 4 | 49.76 | -2 | 58.88 | 8.73 | 24.69 | -2 | 45.22 | 3.62 |
| 3.35 | 43.35 | -1.675 | 67.61 | 7.61 | 29.17 | -1.675 | 48.84 | 4.27 |
| 2 | 58.25 | -1 | 75.22 | 10.22 | 58.52 | -1 | 53.11 | 8.57 |
| 1.4 | 22.63 | -0.5 | 85.44 | 3.97 | 46.36 | -0.5 | 61.68 | 6.79 |
| 1 | 11.65 | 0 | 89.41 | 2.04 | 62.78 | 0 | 68.47 | 9.19 |
| 0.71 | 11.99 | 0.5 | 91.45 | 2.1 | 97.62 | 0.5 | 77.66 | 14.3 |
| 0.5 | 12.33 | 1 | 93.55 | 2.16 | 42.77 | 1 | 91.96 | 6.27 |
| 0.25 | 14.75 | 1.5 | 95.71 | 2.59 | 10.6 | 1.5 | 98.23 | 1.55 |
| 0.125 | 9.28 | 2.25 | 98.3 | 1.63 | 1.29 | 2.25 | 99.78 | 0.19 |
| 0.063 | 0.29 | 4 | 99.93 | 0.05 | 0.2 | 4 | 99.97 | 0.03 |
| <.063 | 0 | >4 | 99.98 | 99.98 | 0 | >4 | 100 | 100 |
| | 569.94 | | | | 682.67 | | | |

**Table 22** Grain Size Distribution data from CS5RB1 and CS7L1

| Sieve size (mm) | CS5RB1 | | | | CS7L1 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 25 | 0 | -4.56 | 0 | 0 | 0 | -4.56 | 0 | 0 |
| 12.5 | 78.94 | -3.56 | 0 | 12.97 | 75.2 | -3.56 | 0 | 9.52 |
| 9.5 | 44.32 | -3.25 | 12.97 | 7.28 | 51.41 | -3.25 | 9.52 | 6.51 |

| Sieve size (mm) | CS5RB1 | | | | CS7L1 | | | |
|---|---|---|---|---|---|---|---|---|
| | weight(g) | phi | Cum% | weight % | weight(g) | phi | Cum% | weight % |
| 6.3 | 71.77 | -2.575 | 20.25 | 11.79 | 75.03 | -2.575 | 16.03 | 9.5 |
| 4.75 | 41.8 | -2.25 | 32.04 | 6.87 | 68.53 | -2.25 | 25.53 | 8.68 |
| 4 | 25.87 | -2 | 38.91 | 4.25 | 54.37 | -2 | 34.21 | 6.88 |
| 3.35 | 30.15 | -1.675 | 43.16 | 4.95 | 53.17 | -1.675 | 41.09 | 6.73 |
| 2 | 83.49 | -1 | 48.11 | 13.71 | 139.42 | -1 | 47.82 | 17.65 |
| 1.4 | 84.59 | -0.5 | 61.82 | 13.89 | 99.72 | -0.5 | 65.47 | 12.62 |
| 1 | 59.89 | 0 | 75.71 | 9.84 | 48.19 | 0 | 78.09 | 6.1 |
| 0.71 | 59.88 | 0.5 | 85.55 | 9.84 | 44.6 | 0.5 | 84.19 | 5.65 |
| 0.5 | 18.1 | 1 | 95.39 | 2.97 | 38.37 | 1 | 89.84 | 4.86 |
| 0.25 | 7.87 | 1.5 | 98.36 | 1.29 | 30.84 | 1.5 | 94.7 | 3.9 |
| 0.125 | 2.12 | 2.25 | 99.65 | 0.35 | 8.57 | 2.25 | 98.6 | 1.08 |
| 0.063 | 0 | 4 | 100 | 0 | 2.36 | 4 | 99.68 | 0.3 |
| <.063 | 0 | >4 | 100 | 0 | 0.17 | >4 | 99.98 | 0.02 |
| | 608.79 | | 100 | 100 | 789.95 | | 100 | 100 |

### *A2.2 Sediment Source Studies*

#### A2.2.1 Landslide Inventory Mapping

Most of the landslide inventory mapping exercise is completed, with special emphasis on those areas that are drained by the major tributaries demarcated in figure1. The mapped slope failures have been digitized onto 1:15,000 scale aerial photographs and classified as recently active or older slope failures. Many of the landslides have been mapped in the field and detailed measurements taken to assess volumetric displacements of material for sediment source assessment.

**Figures 15 - 26** Landslide Inventory Mapping using Aerial Photographic Interpretation and Field Mapping

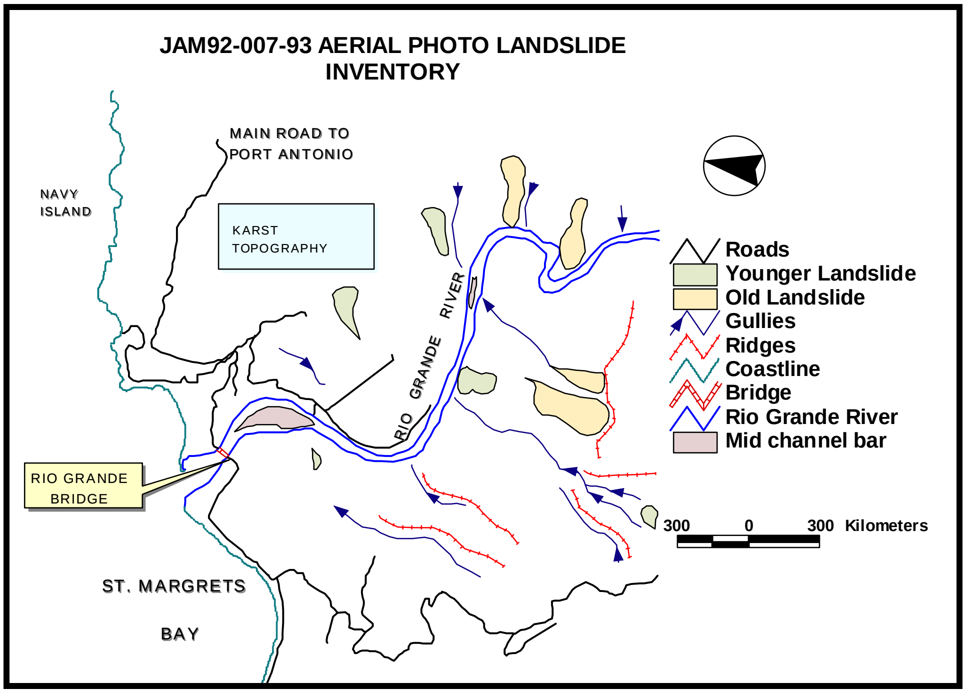



**Fig. 15**

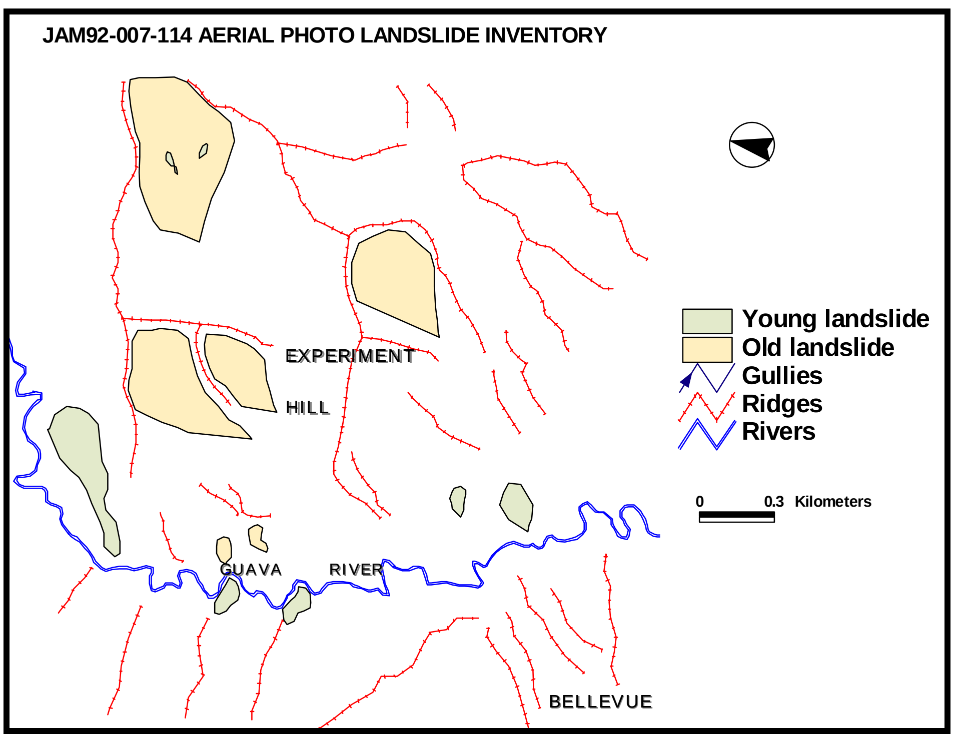



**Fig. 16**

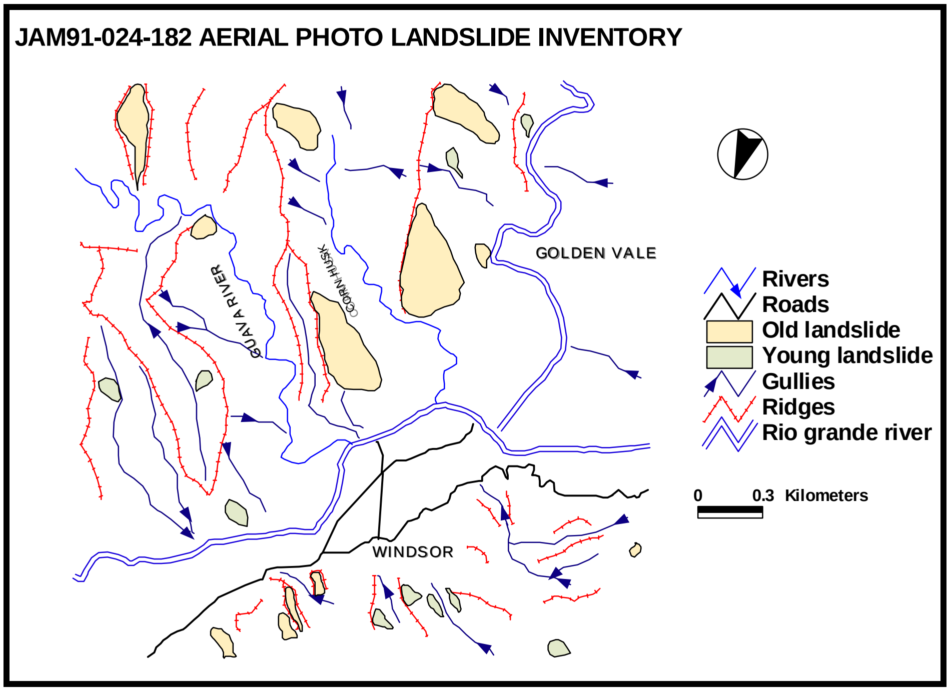

JAM91-024-182 AERIAL PHOTO LANDSLIDE INVENTORY
GOLDEN VALE
GUAVA RIVER
CORN HUSK
WINDSOR
Rivers
Roads
Old landslide
Young landslide
Gullies
Ridges
Rio grande river
0
0.3 Kilometers

**Fig. 17**

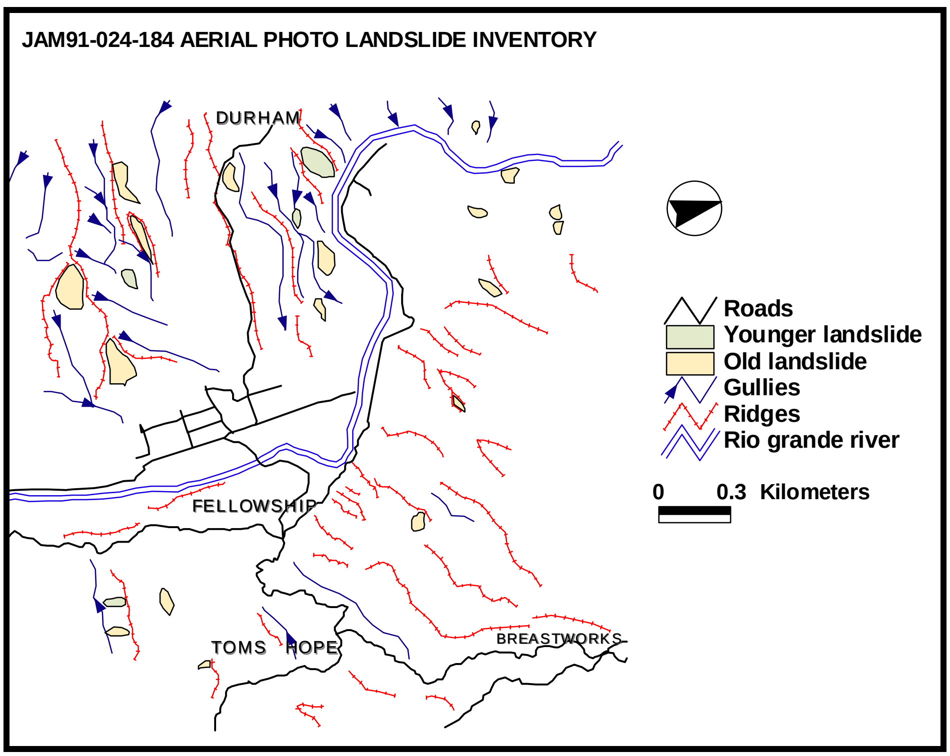

JAM91-024-184 AERIAL PHOTO LANDSLIDE INVENTORY
DURHAM
FELLOWSHIP
TOMS HOPE
BREASTWORKS
Roads
Younger landslide
Old landslide
Gullies
Ridges
Rio grande river
0
0.3 Kilometers

**Fig. 18**

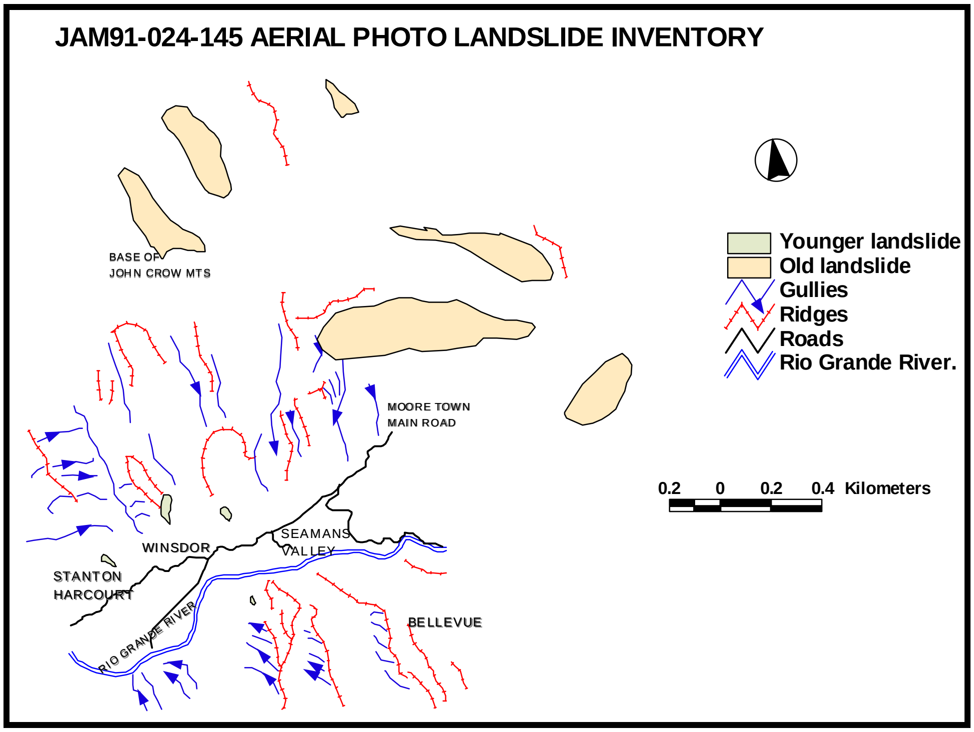

JAM91-024-145 AERIAL PHOTO LANDSLIDE INVENTORY
BASE OF
JOHN CROW MTS
MOORE TOWN
MAIN ROAD
SEAMANS
VALLEY
WINSDOR
STANTON
HARCOURT
RIO GRANDE RIVER
BELLEVUE
Younger landslide
Old landslide
Gullies
Ridges
Roads
Rio Grande River.
0.2 0 0.2 0.4 Kilometers

Fig 19

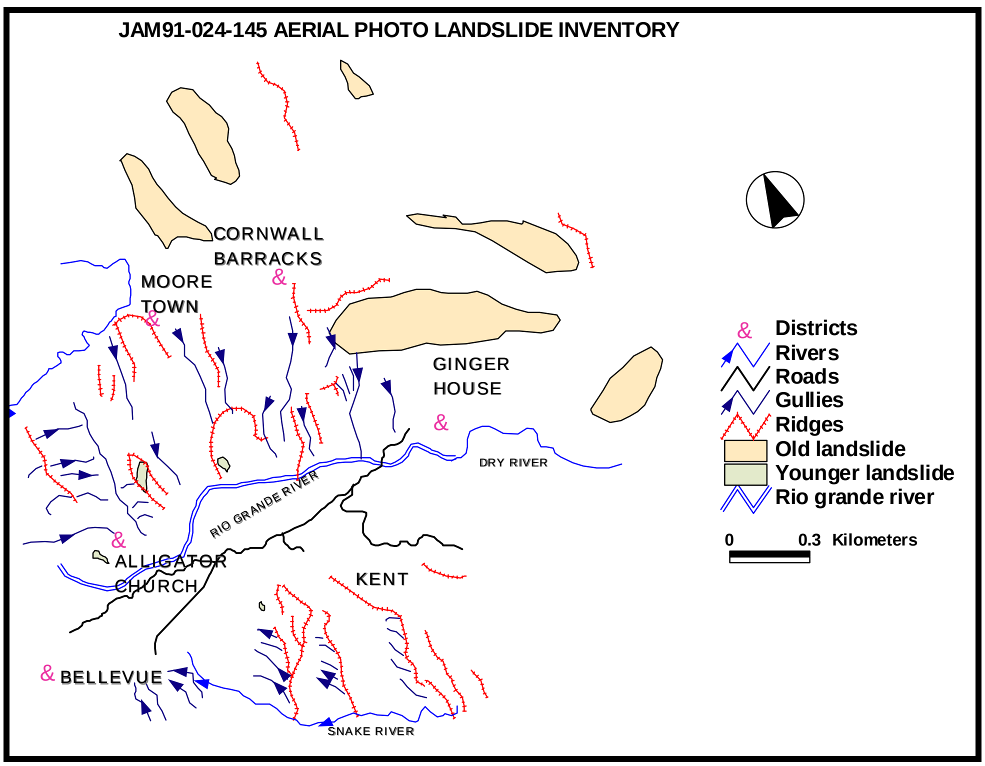

JAM91-024-145 AERIAL PHOTO LANDSLIDE INVENTORY
CORNWALL
BARRACKS
MOORE
TOWN
GINGER
HOUSE
DRY RIVER
RIO GRANDE RIVER
ALLIGATOR
CHURCH
KENT
BELLEVUE
SNAKE RIVER
Districts
Rivers
Roads
Gullies
Ridges
Old landslide
Younger landslide
Rio grande river
0 0.3 Kilometers

Fig. 20

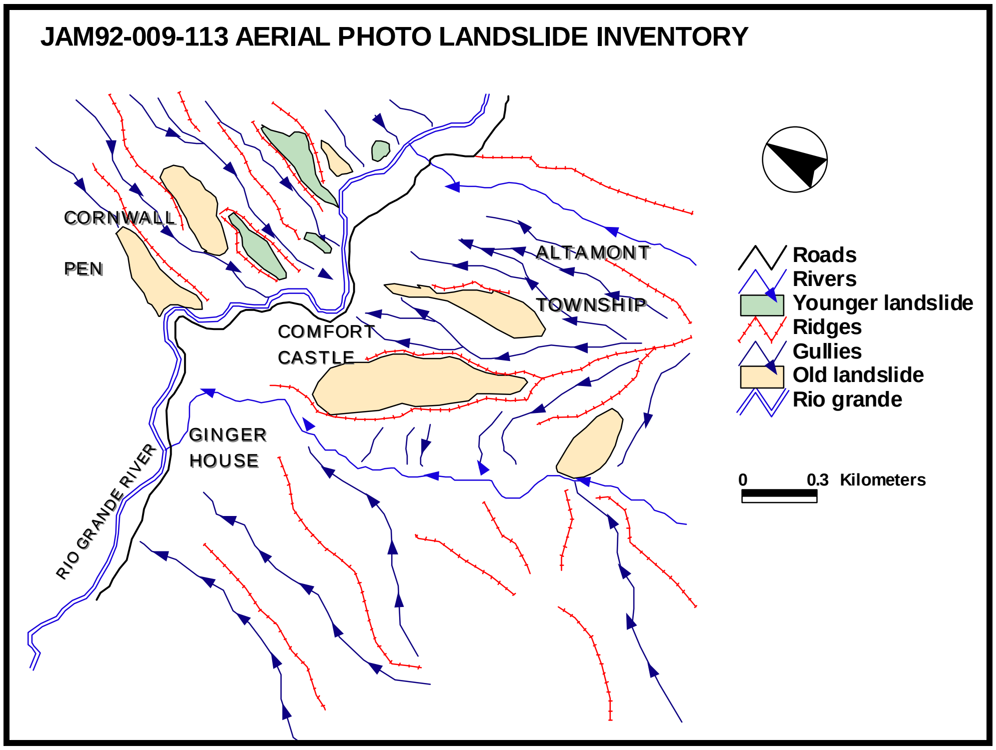

JAM92-009-113 AERIAL PHOTO LANDSLIDE INVENTORY
CORNWALL
PEN
ALTAMONT
TOWNSHIP
COMFORT
CASTLE
GINGER
HOUSE
RIO GRANDE RIVER
Roads
Rivers
Younger landslide
Ridges
Gullies
Old landslide
Rio grande
0
0.3 Kilometers

Fig. 21

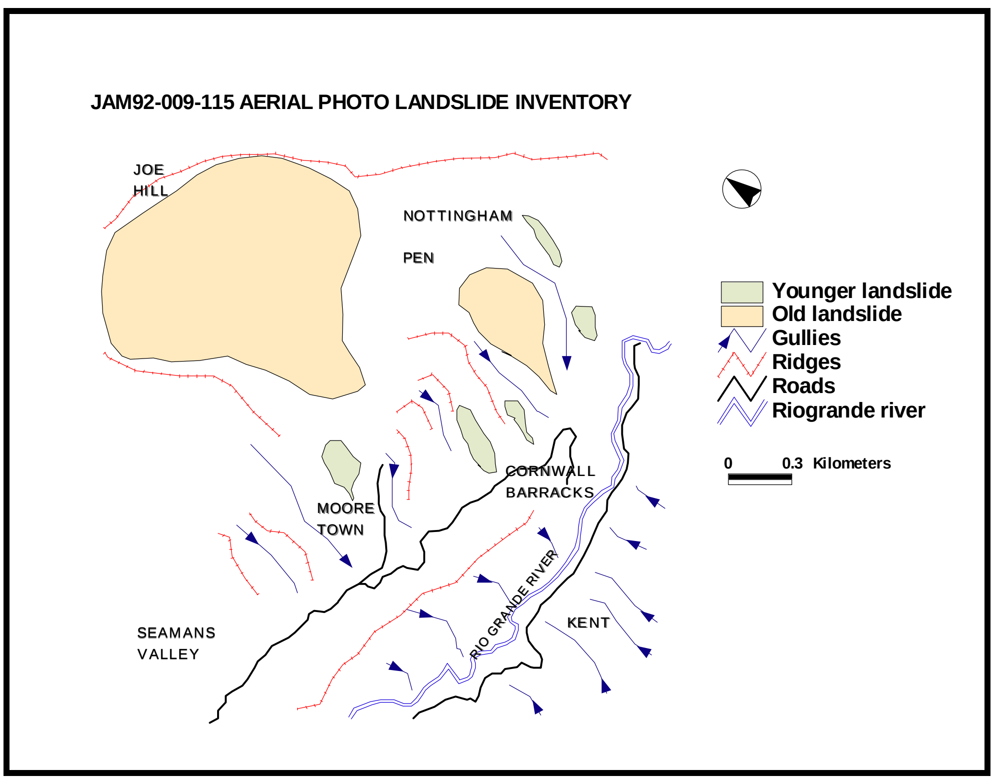
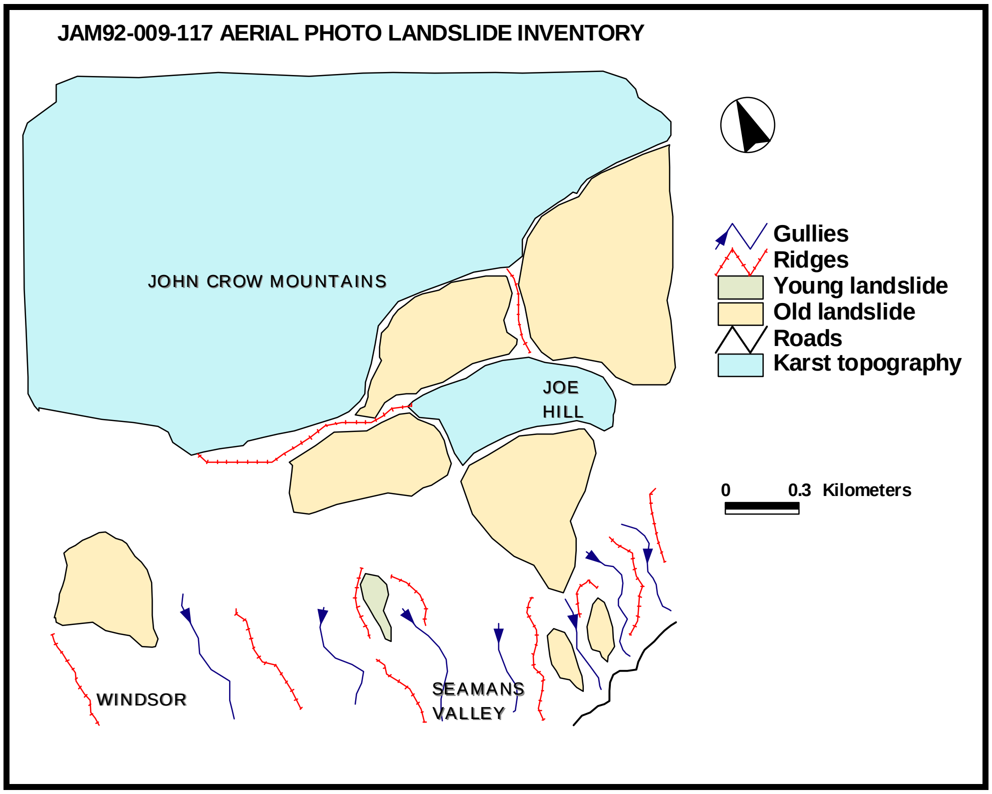
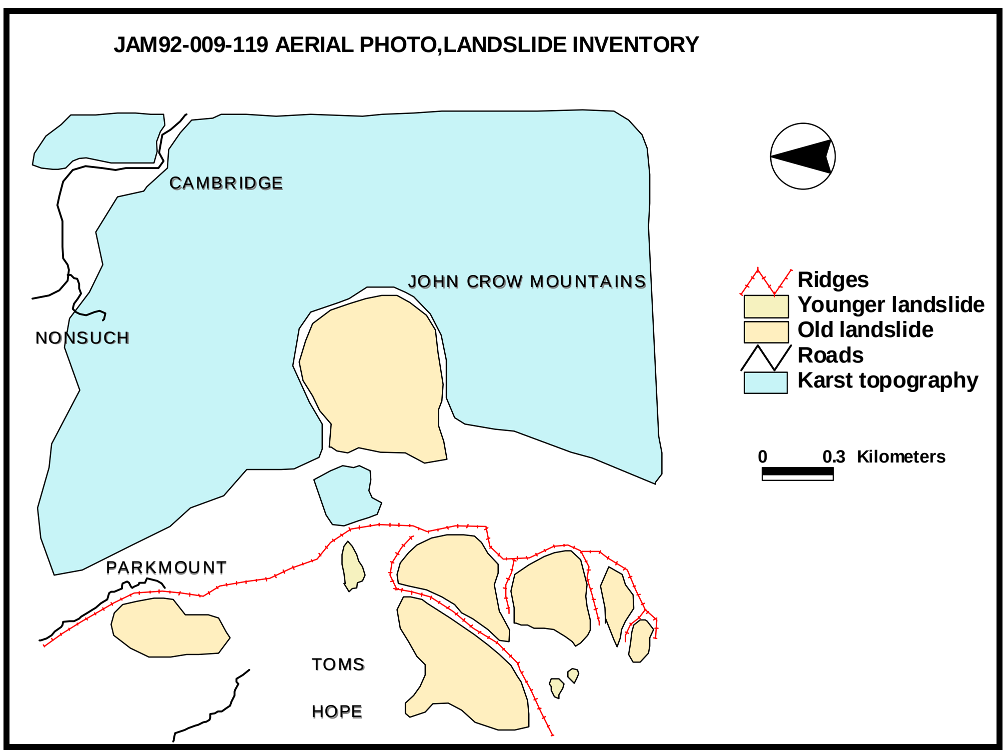

JAM92-009-115 AERIAL PHOTO LANDSLIDE INVENTORY
JOE
HILL
NOTTINGHAM
PEN
CORNWALL
BARRACKS
MOORE
TOWN
SEAMANS
VALLEY
RIO GRANDE RIVER
KENT
Younger landslide
Old landslide
Gullies
Ridges
Roads
Riogrande river
0
0.3 Kilometers

Fig. 22



JAM92-009-117 AERIAL PHOTO LANDSLIDE INVENTORY
JOHN CROW MOUNTAINS
JOE
HILL
WINDSOR
SEAMANS
VALLEY
Gullies
Ridges
Young landslide
Old landslide
Roads
Karst topography
0
0.3 Kilometers


Fig. 23



JAM92-009-119 AERIAL PHOTO,LANDSLIDE INVENTORY
CAMBRIDGE
JOHN CROW MOUNTAINS
NONSUCH
PARKMOUNT
TOMS
HOPE
Ridges
Younger landslide
Old landslide
Roads
Karst topography
0
0.3 Kilometers


Fig. 24

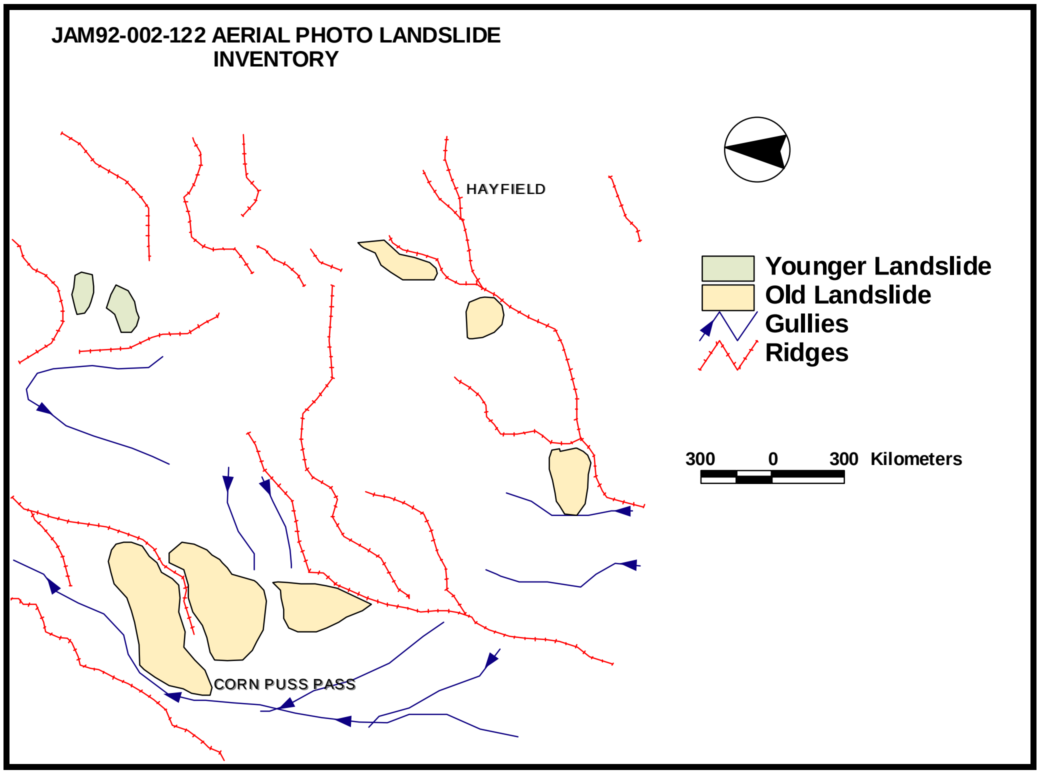

JAM92-002-122 AERIAL PHOTO LANDSLIDE
INVENTORY
HAYFIELD
CORN PUSS PASS
Younger Landslide
Old Landslide
Gullies
Ridges
300 0 300 Kilometers

Fig. 25

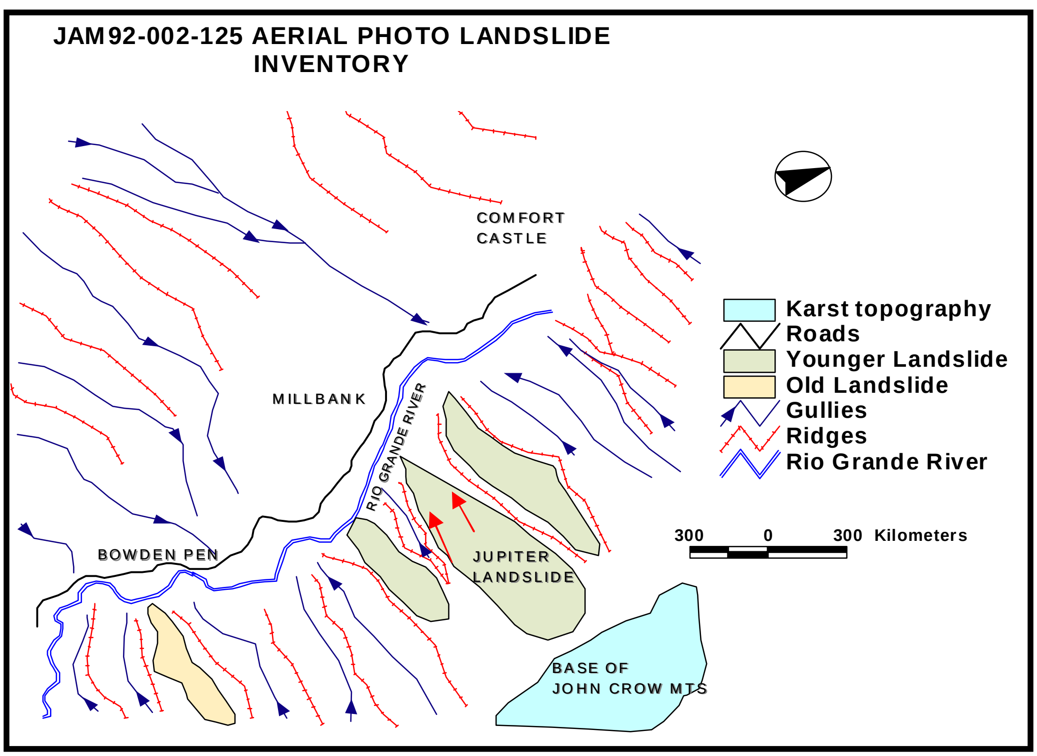

JAM92-002-125 AERIAL PHOTO LANDSLIDE
INVENTORY
COMFORT
CASTLE
MILLBANK
RIO GRANDE RIVER
BOWDEN PEN
JUPITER
LANDSLIDE
BASE OF
JOHN CROW MTS
Karst topography
Roads
Younger Landslide
Old Landslide
Gullies
Ridges
Rio Grande River
300 0 300 Kilometers

Fig. 26

### *A2.3 Sediment Discharge and Yield Studies*

Fortnightly suspended sediment sampling continued at Fellowship Bridge, together with limited sampling at the main Rio Grande Bridge. The results of the sampling are shown in tables 22 and 23. Most of the samples were collected at Fellowship Bridge, as there is a WRA gauging station at that site which can be used to determine a suspended sediment rating curve with discharge. The total suspended sediment determined as g/ml, will be converted to the standard mg/l measurement.

**Table 23** Suspended Sediment Samples for Type Section - Rio Grande Bridge

| Date Collected | Suspended Sediment (g/ml) | | | Total Suspended Sediment (g /ml) | | | TSS Average |
|---|---|---|---|---|---|---|---|
| | Left Bank | Centre Bank | Right Bank | Left Bank | Centre Bank | Right Bank | |
| 22/02/2004 | 0.47/160 | 1.85/146 | 2.44/145 | 0.00294 | 0.0127 | 0.0168 | 0.01081333 |
| 13/03/2004 | 0.88/198 | 1.02/135 | 1.46/200 | 0.0044 | 0.0785 | 0.0073 | 0.03006667 |

**Table 24** Suspended Sediment Samples for Type Section - Fellowship Bridge

| Date Collected | State of river | Suspended Sediment(g/ml) | | | Total Suspended Sediment(g/ml) | | | TSS Average (g/ml) |
|---|---|---|---|---|---|---|---|---|
| | | Left Bank | Centre Bank | Right Bank | Left Bank | Centre Bank | Right Bank | |
| 22/02/2004 | Spate | 1.6/110 | 1.77/115 | 2.21/118 | 0.0145 | 0.0154 | 0.0187 | 0.0162 |
| 08/03/2004 | Base Flow | 1.89/431 | 1.62/294 | 1.72/272 | 0.0044 | 0.0055 | 0.0063 | 0.0054 |
| 22/03/2004 | Spate | 1.5/120 | 1.67/130 | 1.58/121 | 0.0125 | 0.0128 | 0.013 | 0.012766667 |
| 05/04/2004 | Base Flow | 1.97/626 | 1.78/635 | 1.91/634 | 0.003 | 0.002 | 0.003 | 0.002666667 |
| 15/04/2004 | Base Flow | 0.9/136 | 1.04/160 | 0.89/145 | 0.0066 | 0.0065 | 0.0061 | 0.0064 |
| 05/09/2004 | Spate | 1.65/166 | 1.69/163 | 0.96/159 | 0.00993 | 0.00966 | 0.00787 | 0.009153333 |
| 22/05/2004 | Spate | 1.88/176 | 1.69/175 | 1.76/172 | 0.01068 | 0.00966 | 0.00994 | 0.010093333 |
| 06/03/2004 | Spate | 1.84/159 | 1.90/162 | 1.82/163 | 0.0116 | 0.0117 | 0.01 | 0.0111 |
| 22/06/2004 | Base Flow | 1.43/155 | 1.52/161 | 1.44/160 | 0.00923 | 0.0094 | 0.009 | 0.00921 |
| Suspended Sediment/Residue Volume-SSRV (g/ml) | | | | | Total Suspended Sediment-TSS (g/ml) | | | |

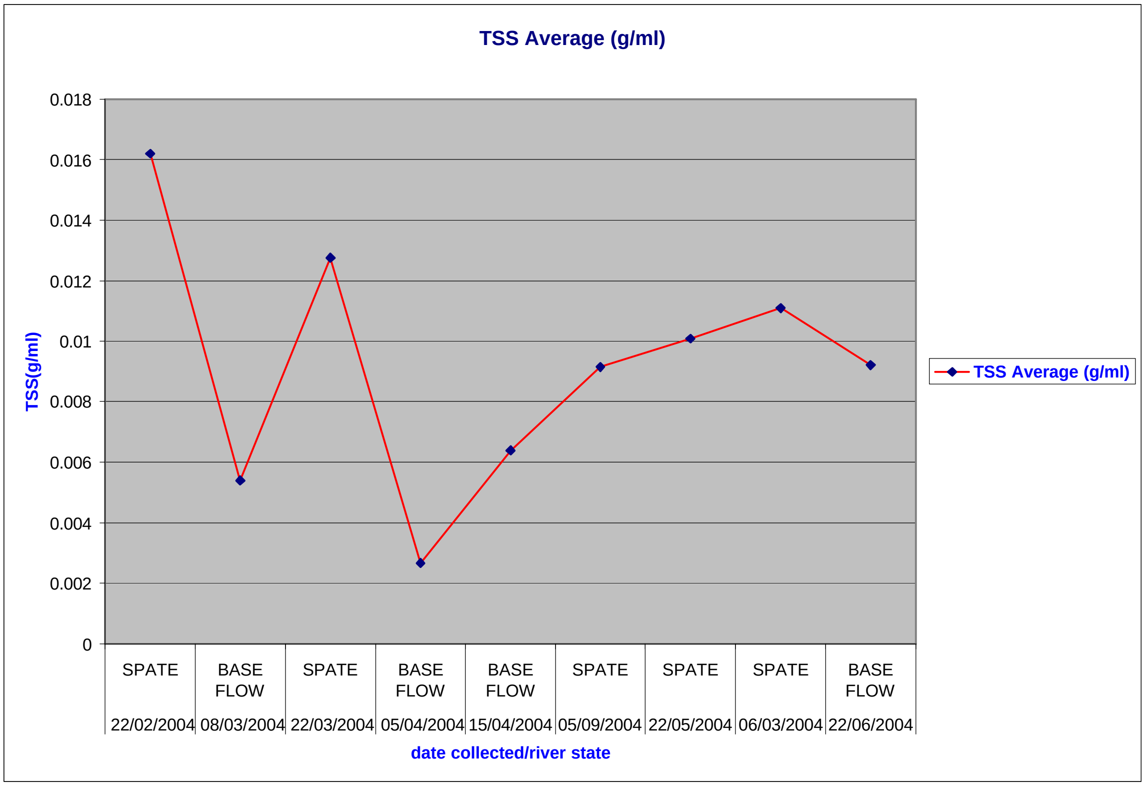



**Figure 27** Total Suspended Solids in River at Various Stages

## A3. Limitations

During the first period of channel cross-section survey, the end survey points on the left and right banks of the river were fixed by steel rods which were spray painted and flagged, so that they could be easily re-located during subsequent survey. However, upon returning to the survey points, it was found that the right bank pegs had been removed from four of the cross-sections and a left bank peg from a fifth survey site. In other words, 25% of the pegs inserted during the first period of survey had been removed This proved to be of nuisance value, as one of the end points of five cross-sections could not accurately be re-located, though the GPS fix, taken during the first survey period was used to approximate the position of the former peg.

# St. Margaret's Bay

### B1. Introduction

The work carried out at St. Margaret's Bay was directed towards two goals. Firstly, the nature of the shoreline, particularly the active beach was investigated and baseline surveys were carried out for ascertaining temporal changes in the extent of the beach, position of the shoreline, and changes in the composition of the beach materials. Secondly, efforts were made to carry out a survey of the topography and sediments constituting the shelf immediately offshore of the beach.

### B2. Beach Profiling

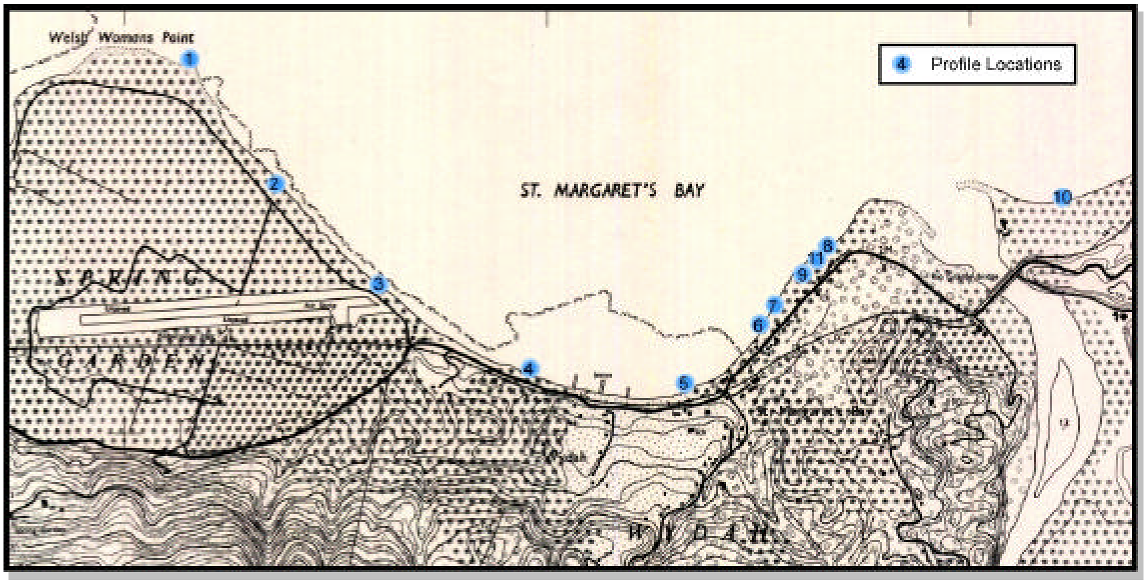



**Figure 28** Location of Beach Profiles Measured along the St. Margaret's Bay Shoreline

Shore-normal beach profiles were re-measured at the 10 locations along the shorelines chosen in February, between Welsh Woman's Point and Rafter's Rest (Figure 8). The survey was carried out using two levels and metric survey staffs. In each case the level was set up at a position which enabled leveling to be effected for the whole profile without the level station having to be moved. Readings of angle and distance to the staff were taken at slope changes along the profile and a note of sediment composition was made at each staff position. Two surveys were carried out in February and April of 2004. On the section of beach between profiles 8 and 9 there was a house that had been damaged as a result of beach erosion. The beach in front of the house had broadened significantly however subsequent visits to the locality showed the beach to eroding once more (Figures 29-31). As a result, an additional profile (#11) was added between profiles #8 and #9 to more closely measure the activity in that area. See picture. A third survey was carried out June, the results of which are included below as Profiles 1 to 11.

**Figure 29** February

**Figure 10** July

**Figure 31** August

Continued measurements of the beach profiles are scheduled for August, 2004.

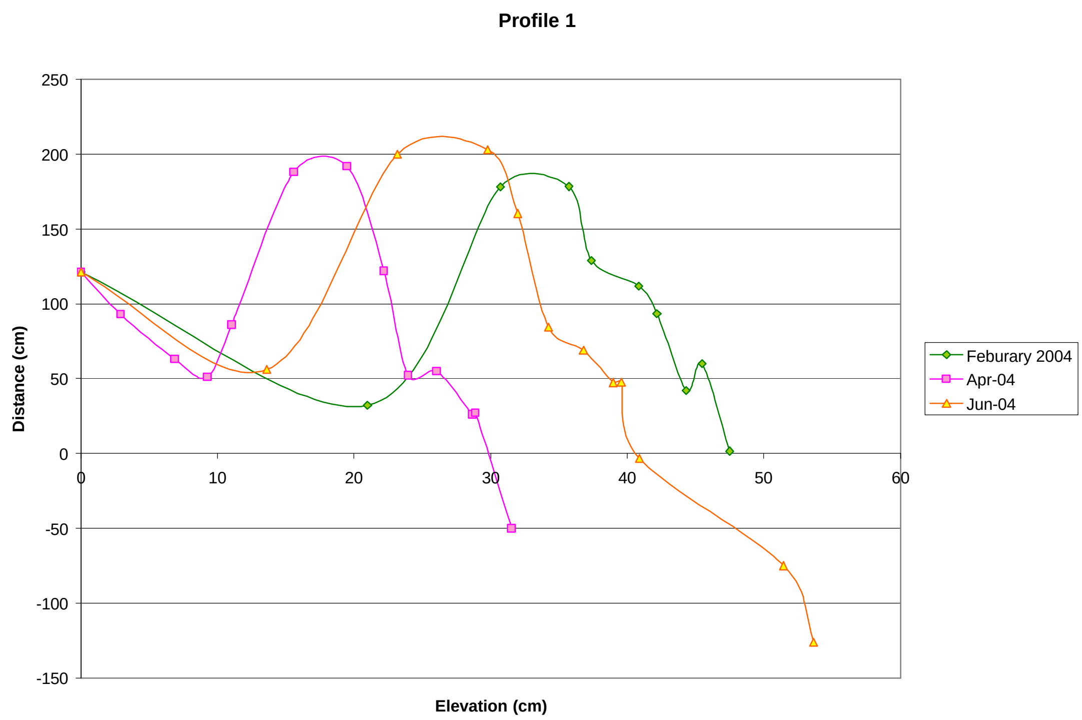



**Figure 32**

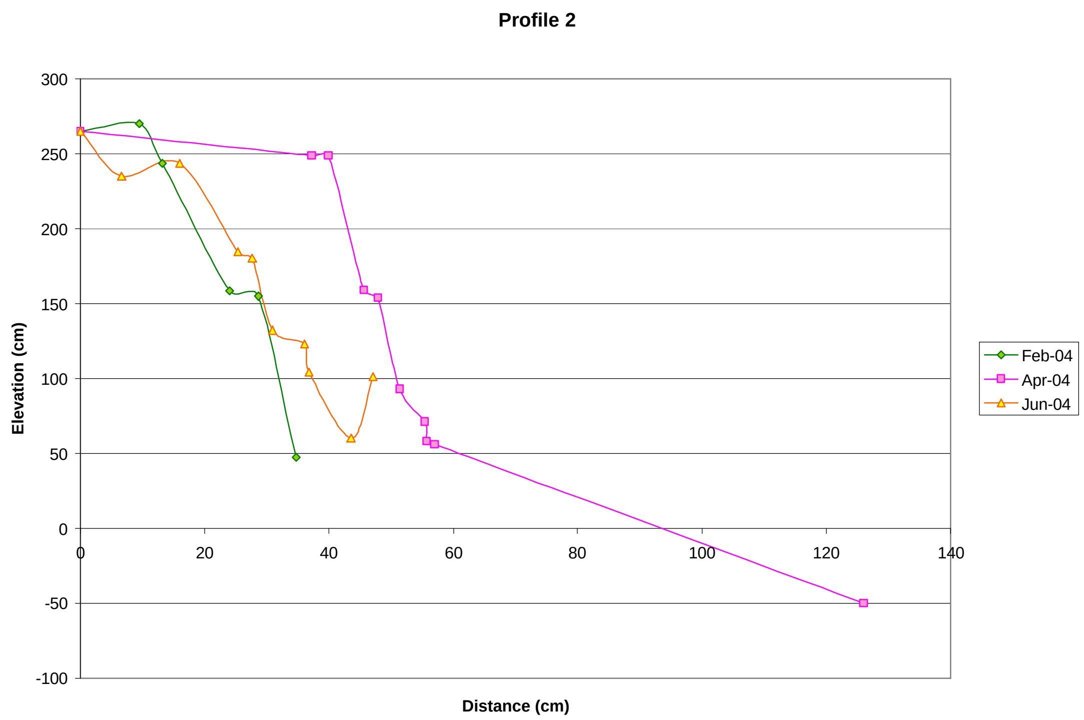



**Figure 32**

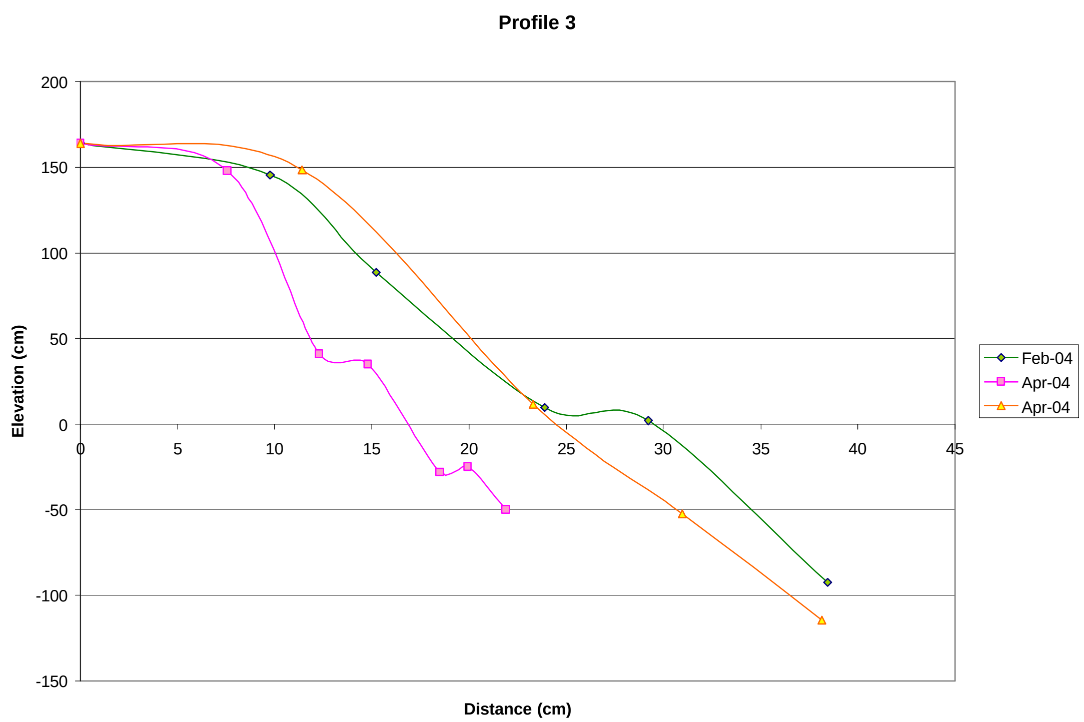



**Figure 33**

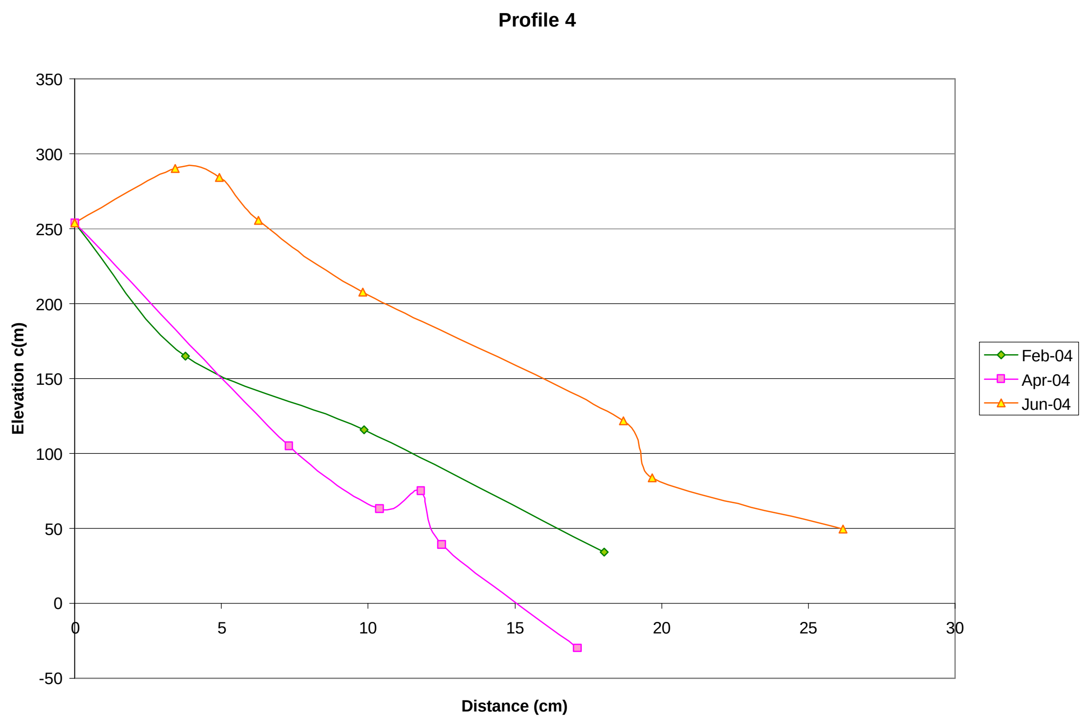



**Figure 34**

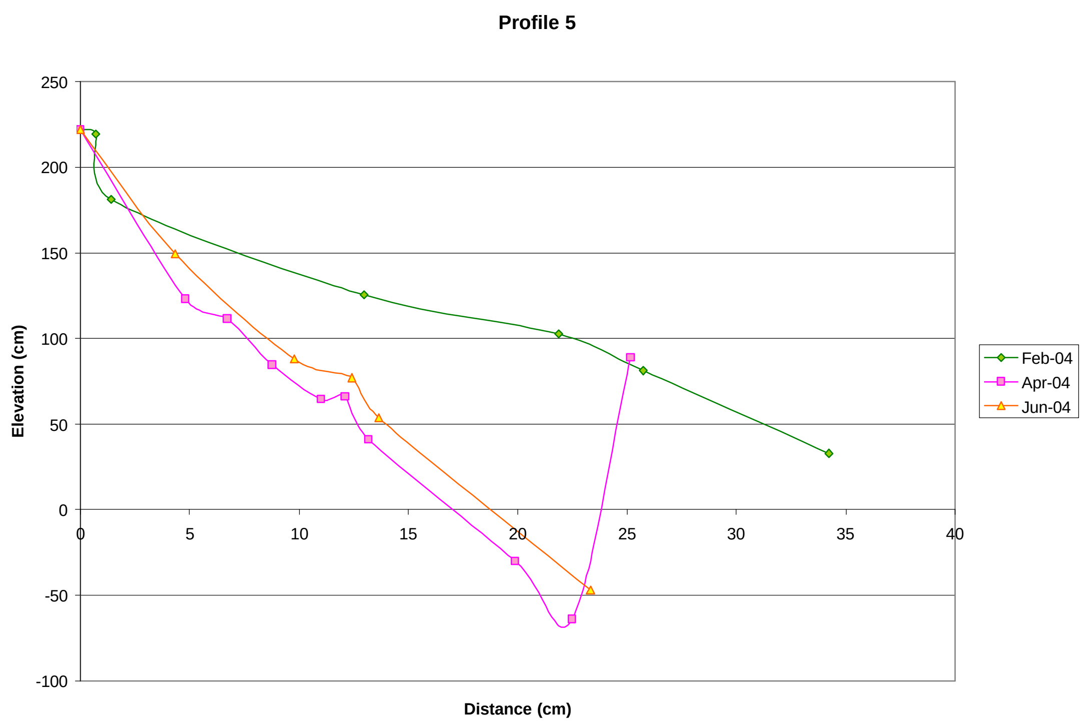



**Figure 35**

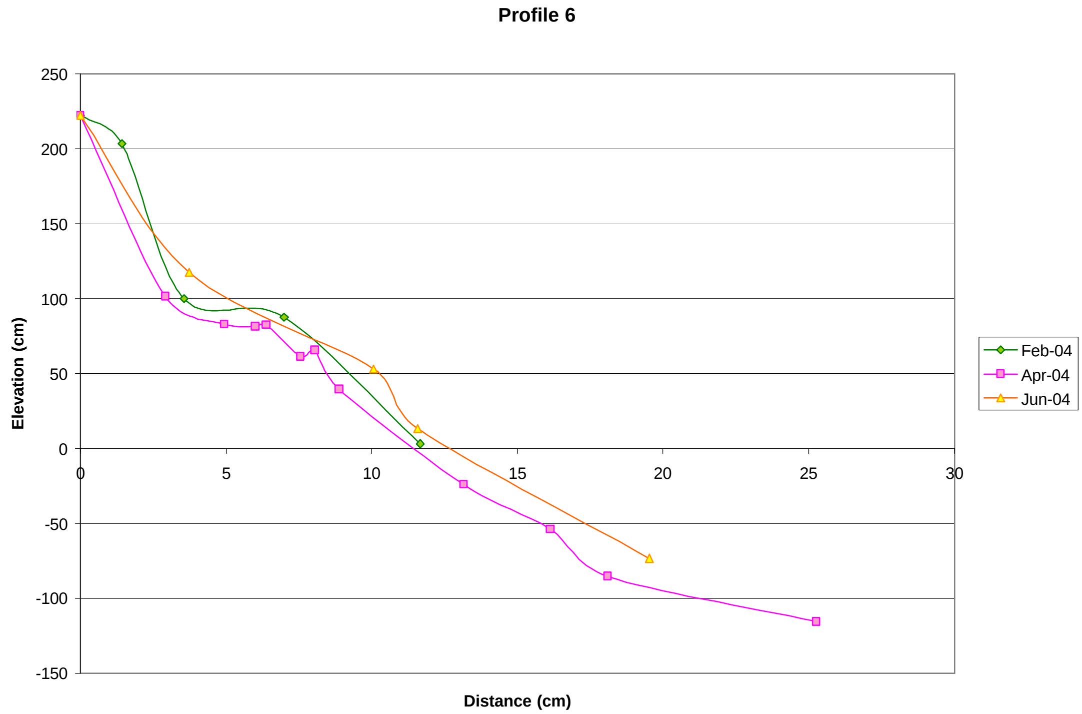



**Figure 36**

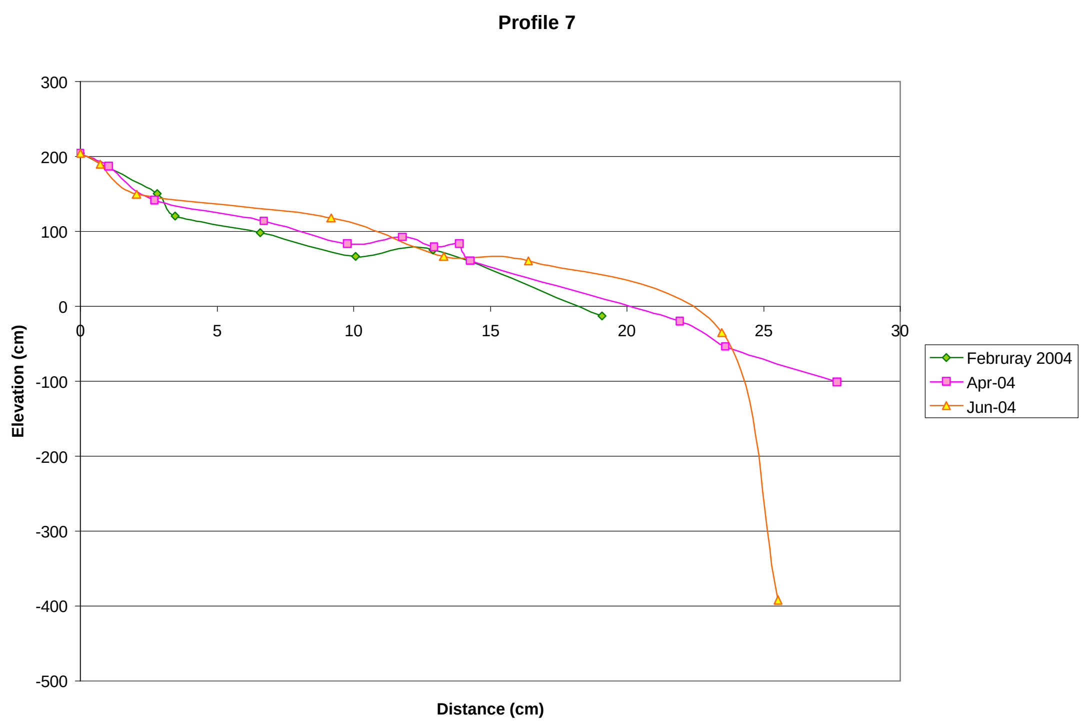



**Figure 37**

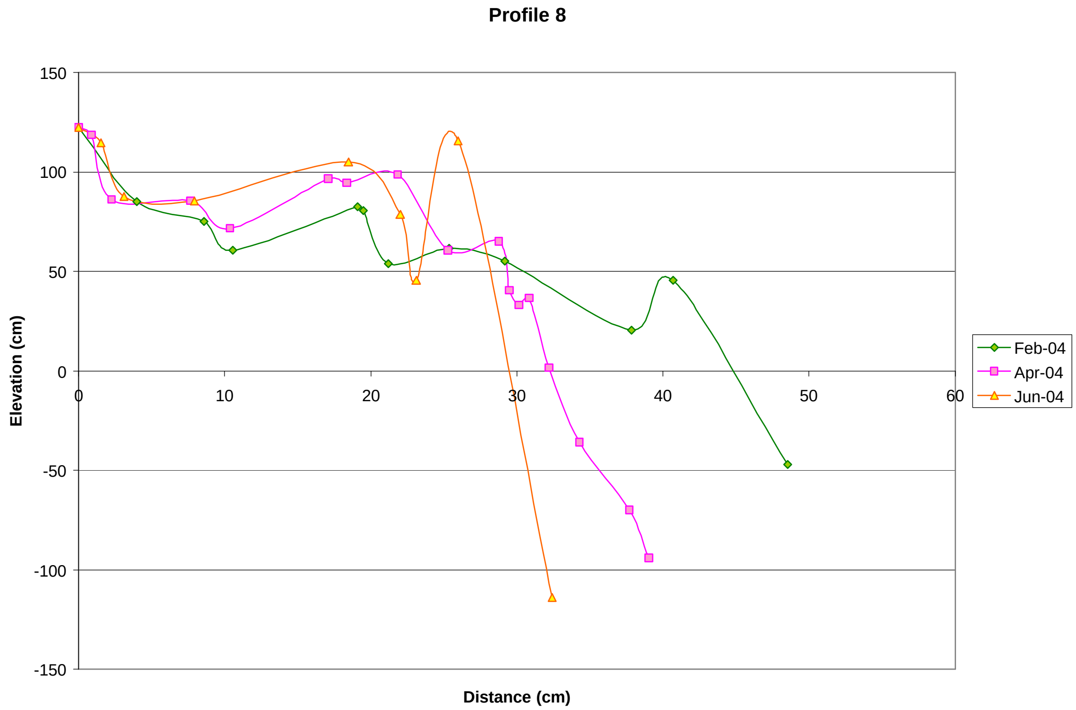



**Figure 38**

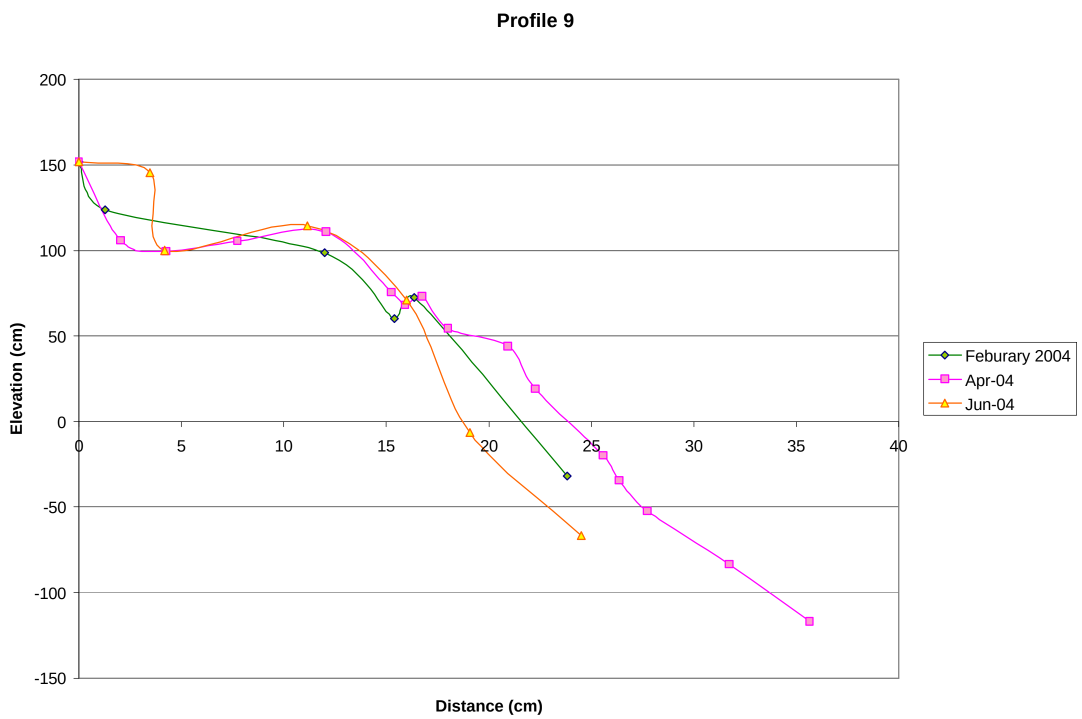



**Figure 39**

Profile 10

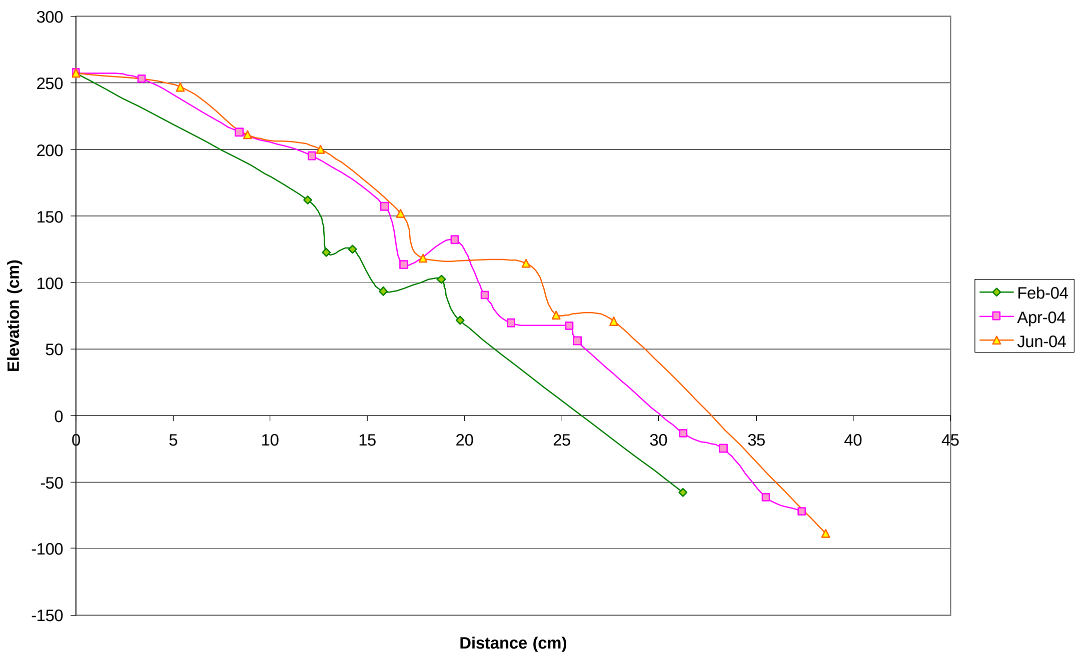



**Figure 40**

## B3. St. Margaret's Bay Bathymetry

A preliminary bathymetry map of St. Margaret's Bay has been completed using depth readings taken using a hand-held depth sounder. The bathymetric contours have been superimposed on the 1:12 500 scale topographic map of St. Margaret's Bay.

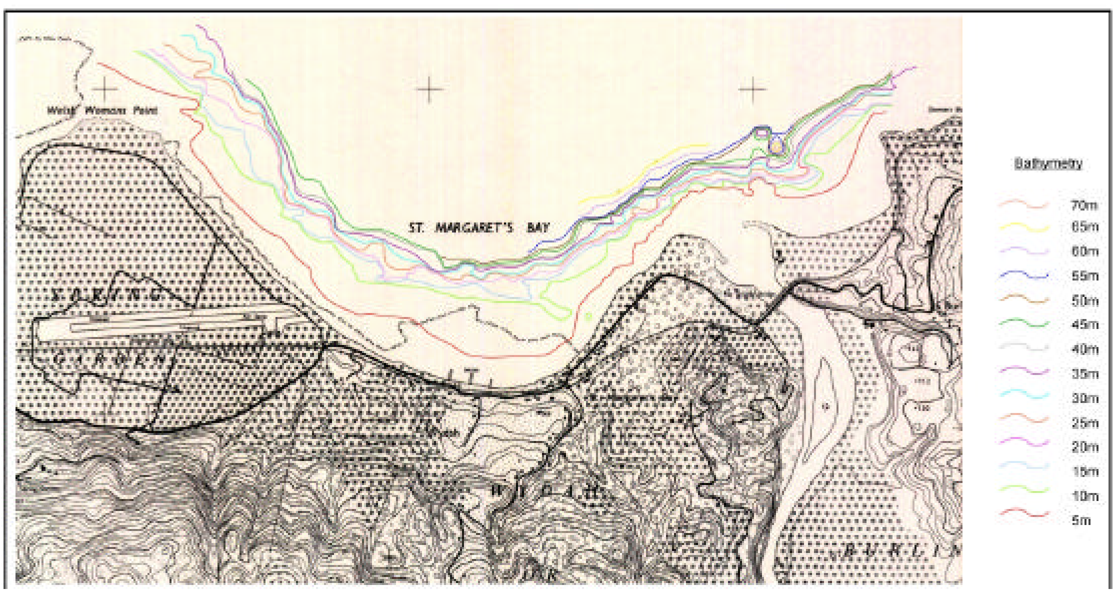



**Figure 41** The Bathymetry of St. Margaret's Bay

## B4. St. Margaret's Bay Grab Sampling

Samples taken from the Bay during depth soundings are described in Table 25 below. The results of the sieve analyses carried out on the samples are illustrated by Figures 41 to 47. The locations from which the grab samples were taken can be seen in Figure 48.

**Table 25** Grab Samples taken from St. Margaret's Bay

| Sample Number | Process | Description of constituents |
|---|---|---|
| 1 | Dry sieved | No carbonate grains evident |
| 2 | Dry sieved | *Halimeda* plates (rare) |
| 3 | Wet sieved | *Halimeda* plates; Gastropod; Echinoid spines & plates; Foraminifera; sea grass |
| 4 | Dry sieved | *Halimeda* fragments |
| 5 | Dry sieved | *Halimeda* plates (rare) |
| 6 | Dry sieved | No carbonate grains evident |
| 7 | Wet sieved | *Halimeda* plates; Gastropod (rare); Foraminifera (rare) |
| 8 | Dry sieved | *Halimeda* plates; Amphiroa fragments; Gastropod; Foraminifera; sponge spicules |
| 9 | Dry sieved | *Halimeda* plates; Amphiroa fragments; Gastropod; Foraminifera; sponge spicules |
| 10 | * | No carbonate grains evident |
| 11 | Dry sieved | Gastropod fragments |
| 12 | Wet sieved | Indeterminable |

* Sample size was insufficient for sieve analysis

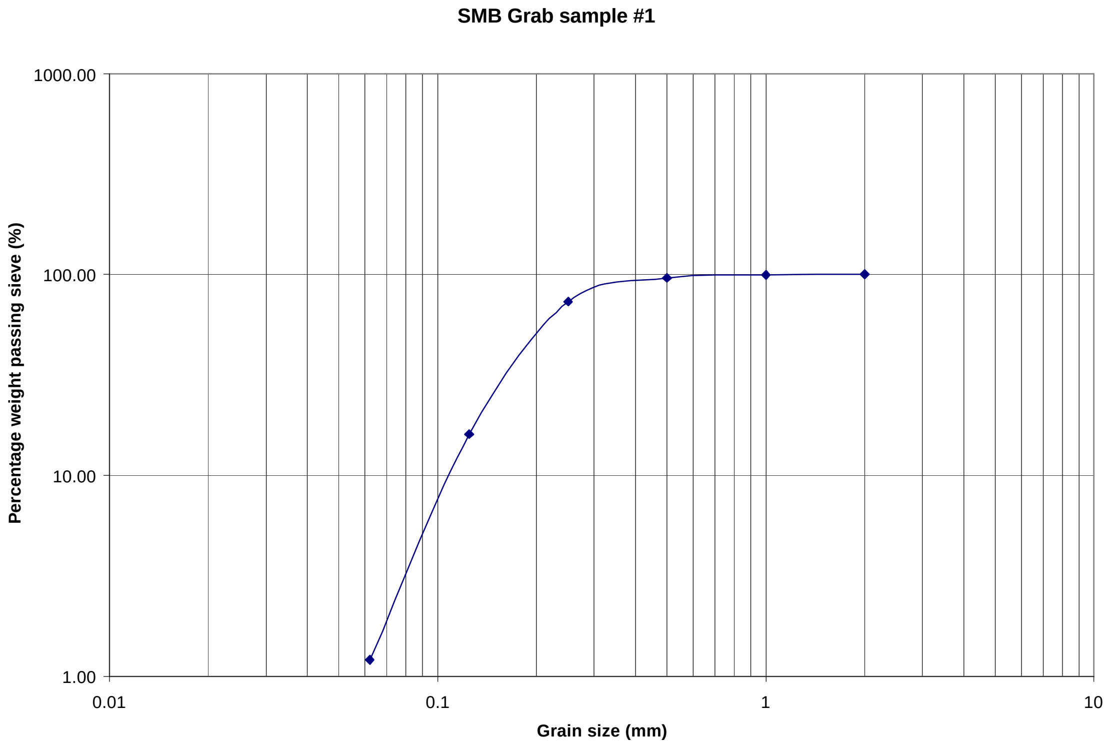



**Figure 41**

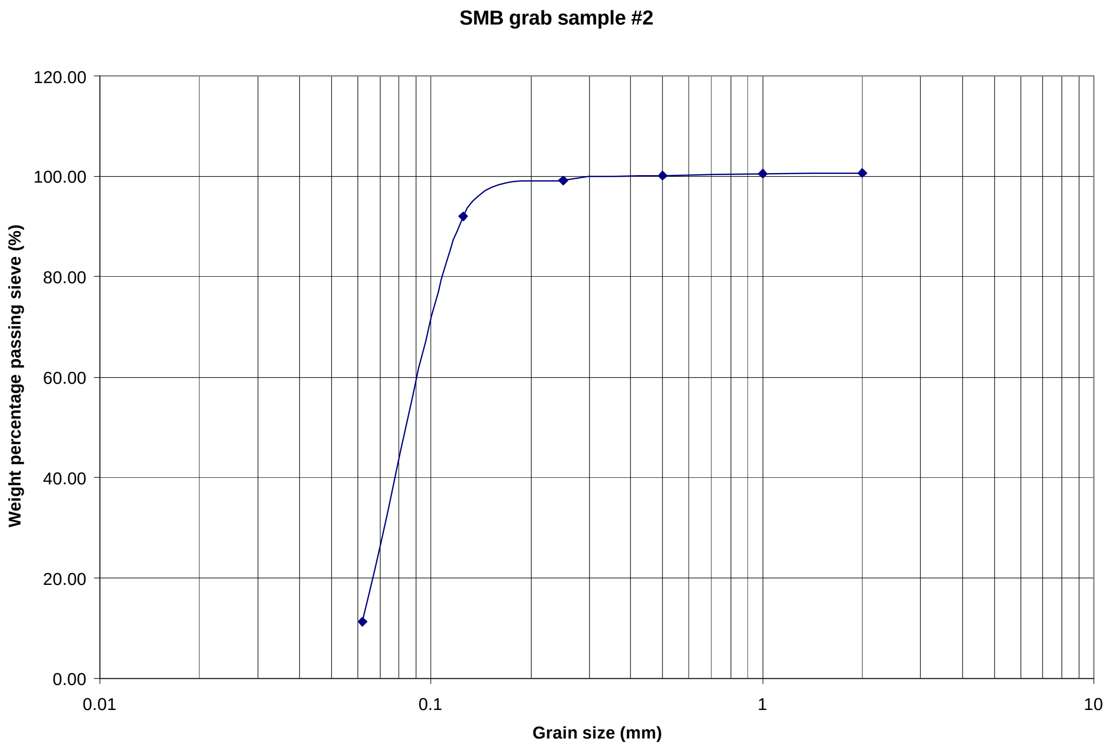



**Figure 42**

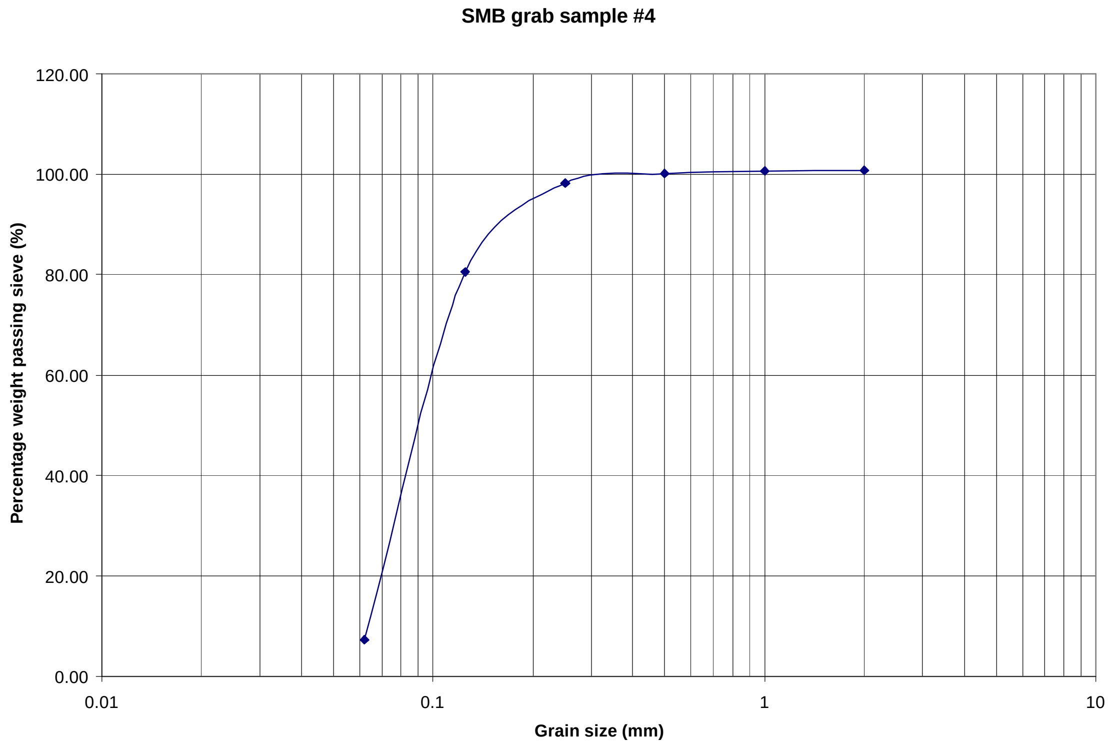



**Figure 43**

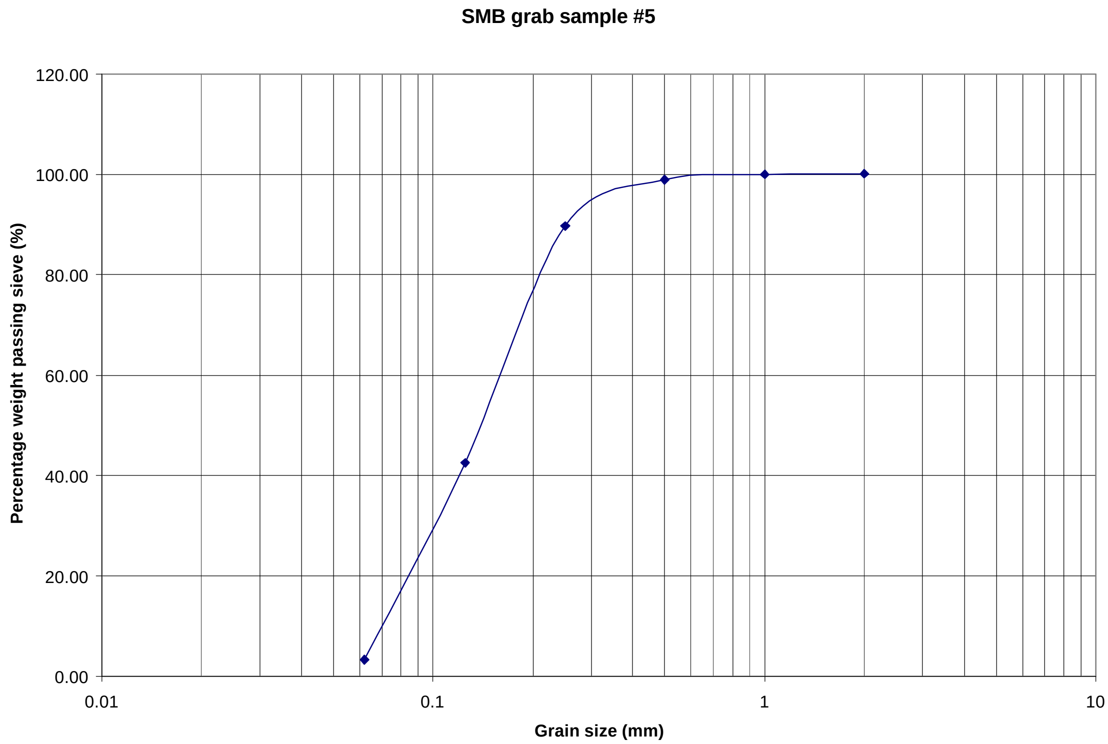



**Figure 44**

SMB grab sample #8

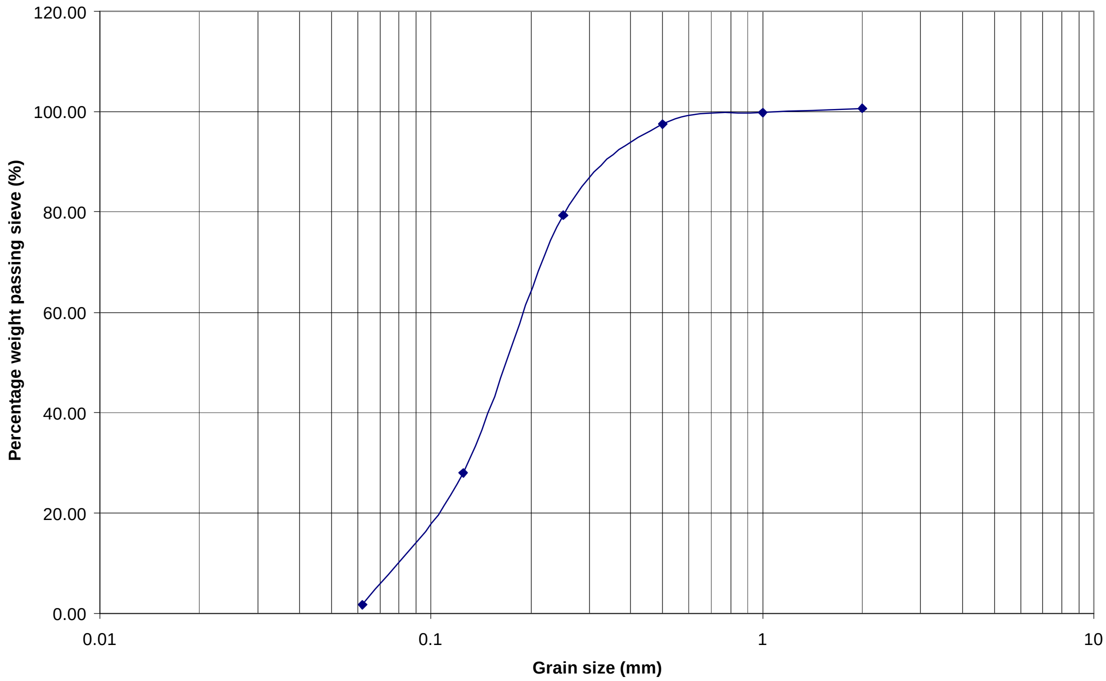



**Figure 45**

SMB grab sample #9

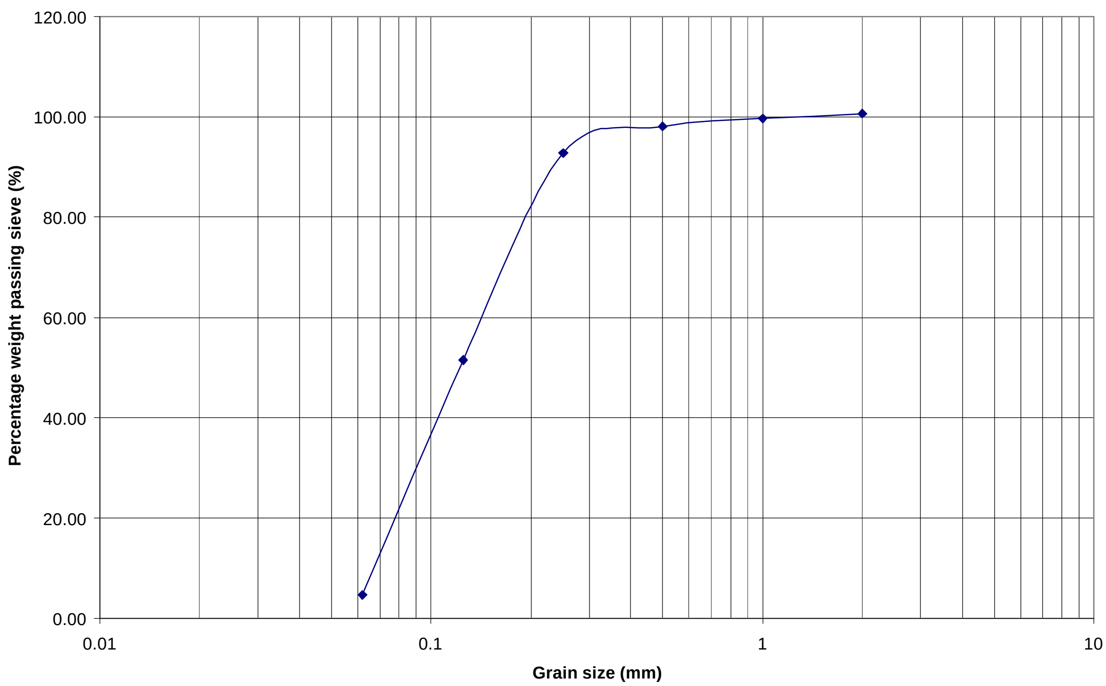



**Figure 46**

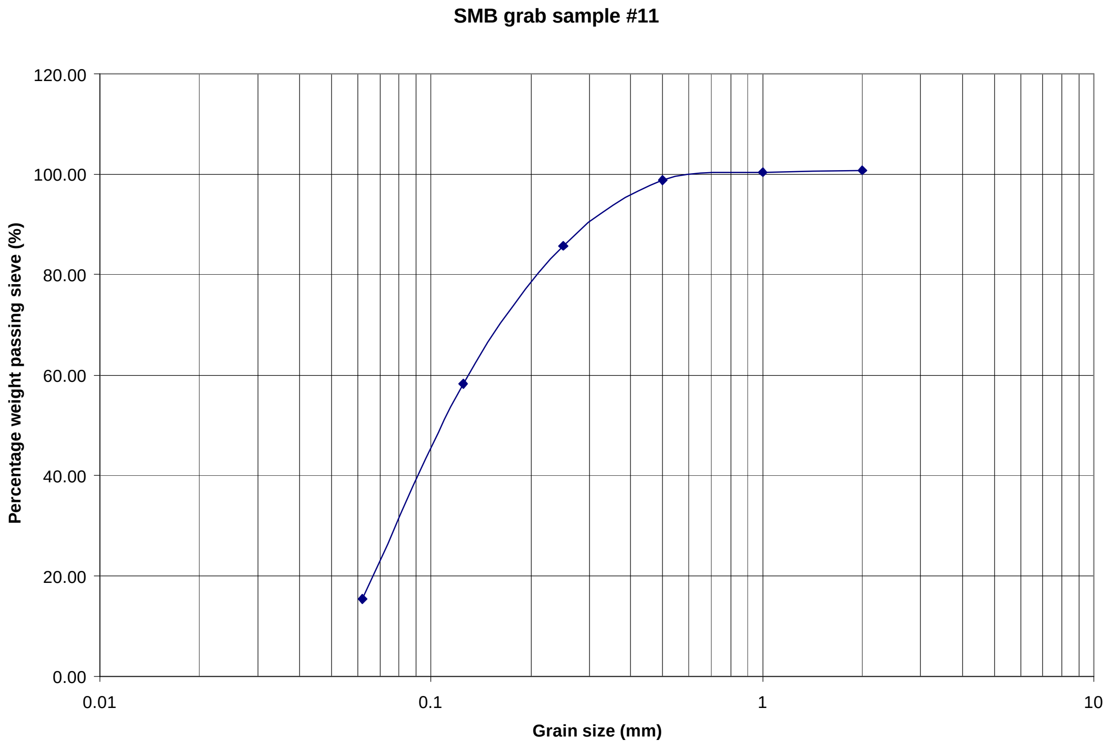



**Figure 47**

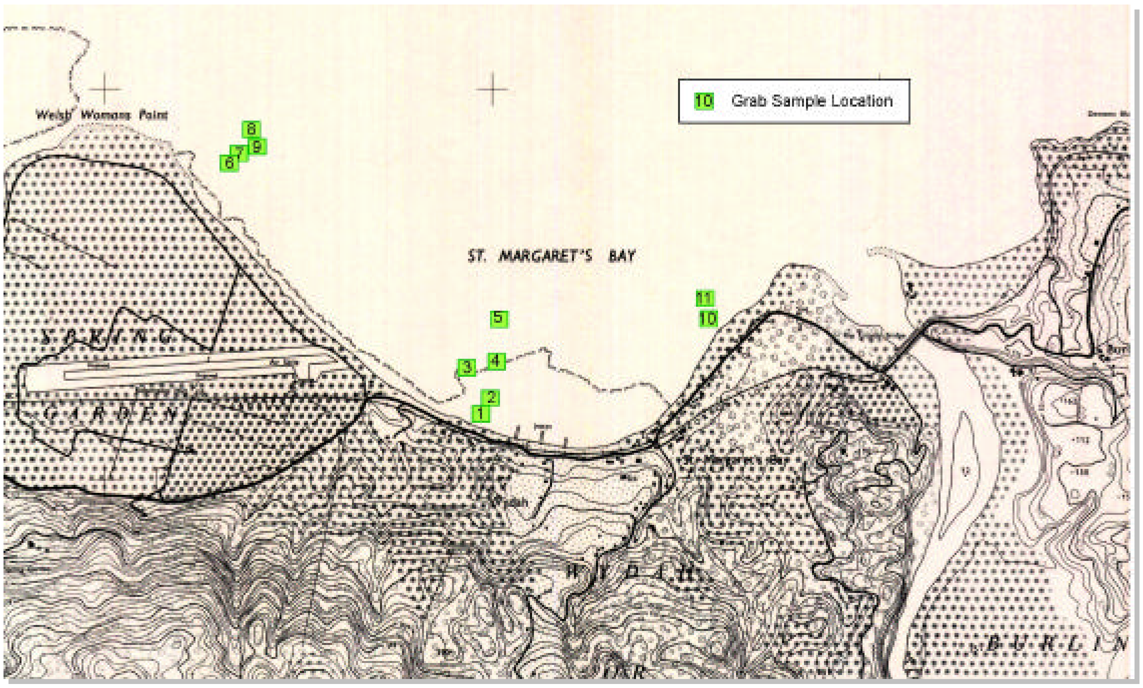



**Figure 48** Locations from Which Grab Samples were Taken

**Ridge to Reef Watershed Project**