LARGE GRAVEL/COBBLE SUBMARINE DUNES IN GRAND PASSAGE, NOVA SCOTIA: ARE THEY DEAD OR ALIVE?

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ABSTRACT

The Bay of Fundy is home to the world's highest recorded tides and consists of several channels within Digby County, Nova Scotia, Canada. Each of the channels, including Digby Gut, Petit Passage, and Grand Passage, show the occurrence of dune formations in high resolution from bathymetry data collected with multi-beam sonar. Grand Passage was the location chosen for this study since sets of well-formed dunes are present in relatively shallow water. However, it is unknown whether these dune formations are mobile or static. The interpretation of dune mobility comes from knowledge of the geology of the area, available data on current speeds, and video footage collected in Grand Passage as part of this project. The surrounding geology is composed predominately of North Mountain Basalt, an early Jurassic formation. The separation of Brier and Long Island, forming Grand Passage, is thought to be a result of strike-slip faulting between the two islands, followed by fluvial and glacial erosion. Experimentation was conducted using a rectangular frame made of PVC piping and two GoPro cameras to capture video footage of the seabed at the southern entrance to Grand Passage. Still images captured from the video footage were then analyzed to determine grain size along the channel axis and mobility parameters were calculated from the observed grain sizes. Results showed that the dunes consist of mainly cobble grains (Wentworth scale, 64 – 256 mm) with abundant biological material. The critical Shields parameter and particle Reynolds number were calculated for the average grain size diameters found in each still and compared to a mobility curve. It is found that the crests of the dunes are active while the dunes become inactive with greater depth.

Keywords: Grain size, mobile, static, crest, Wentworth scale, shields parameter, Reynolds number, mobility curve

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1: Introduction

Chapter 2: Geological Setting

Chapter 3: Methods

Chapter 4: Results

LIST OF TABLES

Chapter 4: Results

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Besides my advisor, I would like to thank Richard Cheel for being there and helping me throughout the entire project. Thank you for lending a huge hand in creating and deploying the instrument used to collect data. As well, thank you for your help in understanding Matlab programming and always making time to explain things further.

I would also like to thank Captain Beau Gillis for the use of his boat and his first mate that assisted in deploying and retrieving the instrument into Grand Passage. As well, I would like to thank Greg Trowse for allowing us to share boat space and time with him during his project "The Great Pumpkin Race: Drones and Drifters".

Finally, I would like to thank my family members and friends who supported me throughout the organization and writing process of this project.

CHAPTER 1: INTRODUCTION

The Bay of Fundy (Figure 1.1) has the highest tides in the world, making it one of Canada’s natural wonders. With tide cycles reaching up to 16 meters that occur every 12 hours and 26 minutes, it is an incredible sight to witness (Bay of Fundy tides, n.d.). Studies are continuously done to ensure that the full potential of the Bay is applied to fishery, energy, and educational exploration. A peninsula called Digby Neck (Figure 1.1) that extends into the Bay has three main channels that cut across the landform called Digby Gut, Petit Passage, and Grand Passage (Fader, 2005). While locals cross these channels by ferry every day, many do not see what is beneath the surface. Bathymetric maps of the channels indicate that dune formations on the channel bed are present in each. The purpose of this study is to determine whether these dune formations are mobile or static.

Grand Passage is the westernmost channel that separates the landmasses on the peninsula and was chosen as the location of interest due to the well-formed dunes offshore of Peter’s Island observed in the bathymetry map (Figure 1.2). To investigate the channel bottom, a rectangular frame made of PVC piping was constructed that could be lowered into the Bay from a local fishing vessel, *School of Fish*. The frame allowed the two GoPro cameras, one facing straight down from the center and one placed at an angle, to have a scale while recording video footage of the channel bed. Following collection of the video footage, stills of the channel bed were captured and examined to see what the average grain sizes are on the channel bed. Whether or not the dunes are active depends on what grain size of the sediments is observed. This paper describes the average grain size of the sediments and potential mobility of the dune formation offshore of Peter’s Island in Grand Passage.

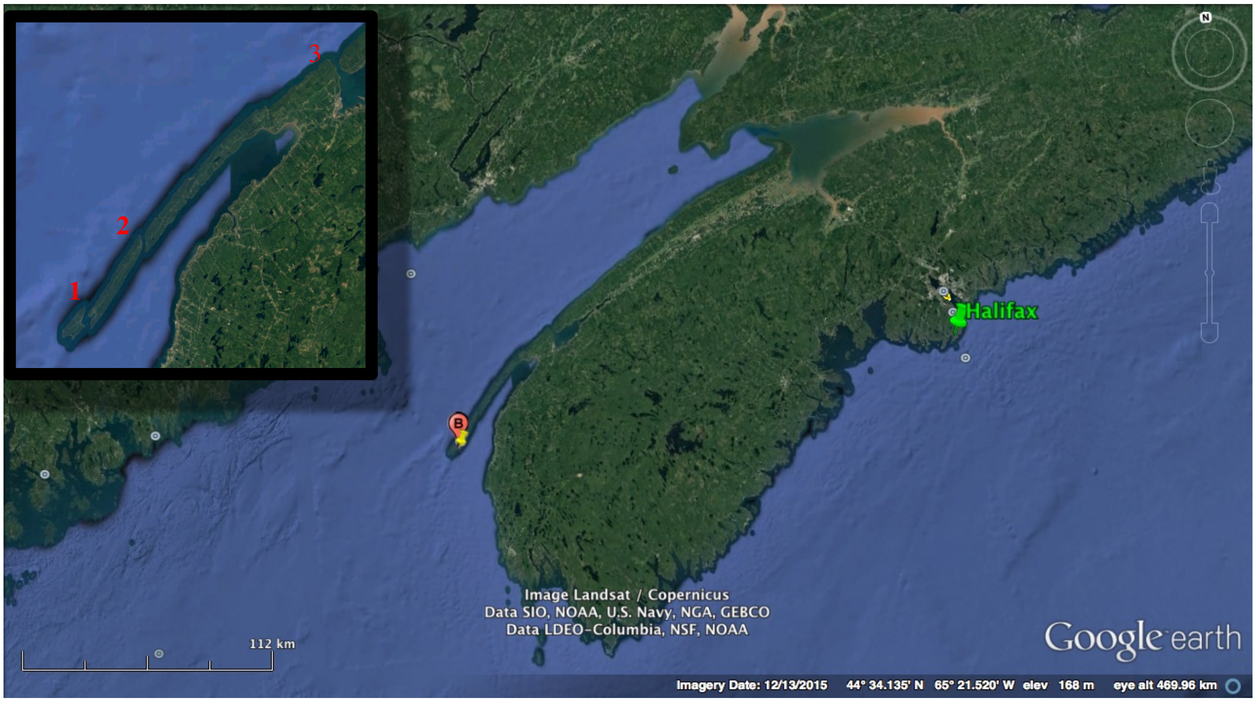


Figure 1.1: Regional map of the Bay of Fundy, Nova Scotia. Halifax and the region of study (marked B) are labeled. Inset indicates location of Grand Passage (1), Petit Passage (2), and Digby Gut (3) (Google Earth, 2015).

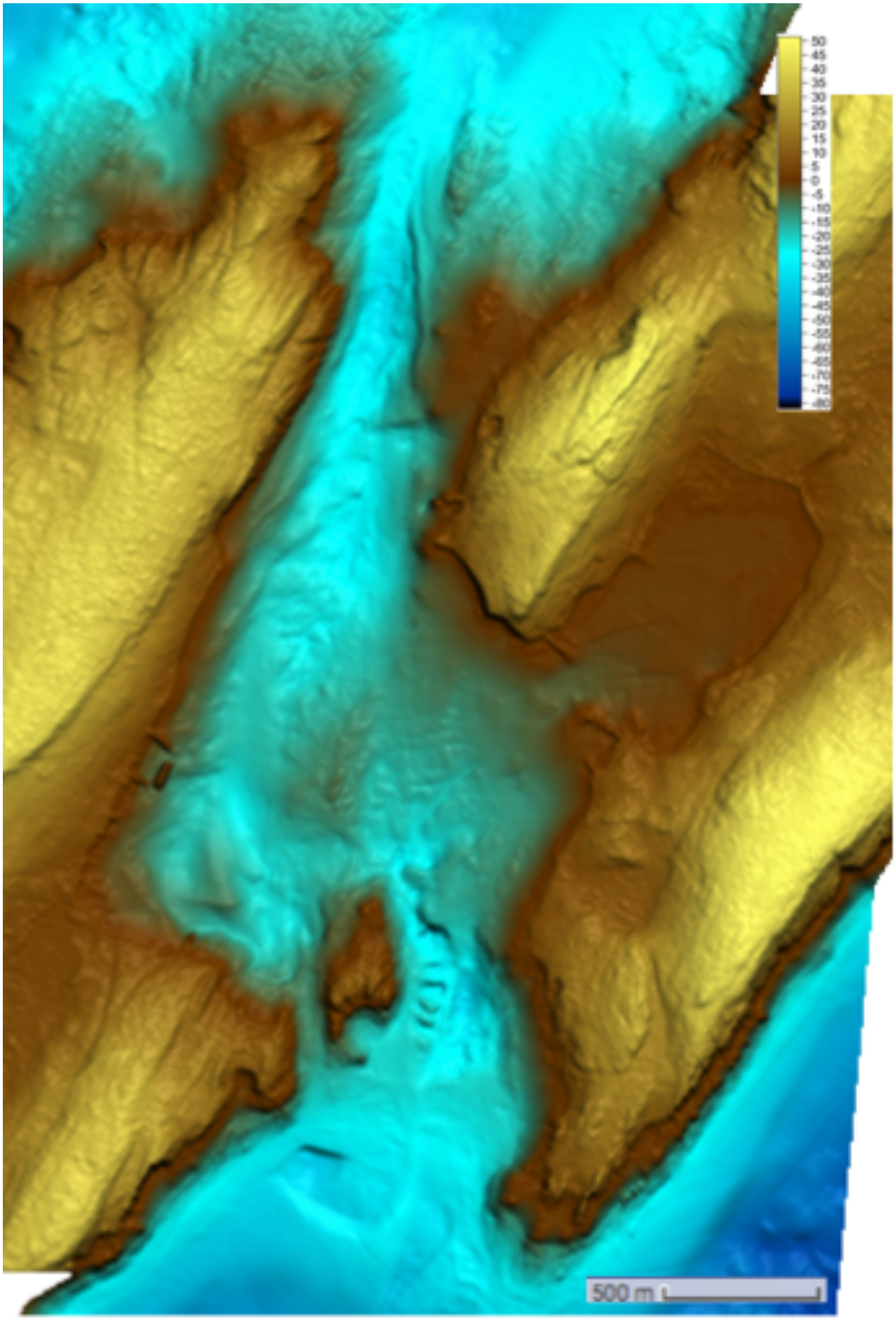


Figure 1.2: Bathymetry map of Grand Passage, Nova Scotia (A. Hay, personal communication, 2016).

CHAPTER 2: GEOLOGICAL SETTING

2.1 Regional Setting

The formation of the Bay of Fundy occurred during the separation of the African and North American continental plates (Geological formation, 2010). The separation caused a basin to be formed between present day State of Maine and New Brunswick on the northwest side, and Nova Scotia on the southeast. The basin eroded over time and filled with water (Geological formation, 2010). Over the next millions of years, the basin would undergo erosion, volcanic activity, and glaciation until it was shaped into the appearance observed today as the Bay of Fundy (Geological formation, 2010).

The Bay of Fundy is funnel-shaped (Figure 1.1), the point being the closest part inland (Fader, 2005). The Bay is 320 km long, with widths ranging from 70 km to 5 km and depths averaging around 75 meters (Canadian Seabed Research Ltd., 2014). The Bay is comprised of mostly Triassic sediments from the Scots Bay Formation (Canadian Seabed Research Ltd., 2014), which consists of red and green siltstone, silicified and stromatolitic limestone, chert, and sandstone (Tanner, 1996). Measurements from seismic reflection profiles show that the Triassic sediments are up to 900 m in thickness, and may be up to 2000 m thick regionally (Fader, 2005).

Seismic reflection profiles also identified a contact between the Scots Bay Formation and the North Mountain Basalt Formation (Fader, 2005). The contact, just offshore along Digby Neck, runs parallel to the shoreline along the entire south coast of the Bay of Fundy (Fader, 2005). The North Mountain Basalt overlays the Triassic sediments as three units (Figure 2.1) referred to as the South Shore member (SSM), Middle member (MM), and North Shore member (NSM) (Kontak, 2001).

2.2 Faulting

Faulting occurs within the North Mountain Basalt units along Digby Neck (Fader, 2005). While these faults do not extend into the overlying Triassic sandstone, they have created offsets that are observed as water gaps (Fader, 2005). The faulting along Digby Neck occurs at Digby Gut, Petit Passage, and Grand Passage (Figure 2.2) (Canadian Seabed Research Ltd., 2014).

2.3 Sea Level Change

The Bay of Fundy is known to have the world’s highest recorded tides, ranging from 3.5 meters to 16 meters depending on location (Bay of Fundy tides, n.d.). To understand the distribution and characteristics of sediments offshore, further knowledge of past sea level change must be noted (Fader, 2005).

Glaciation processes are the main driver of sea level change in the Bay of Fundy’s history (Fader, 2005). The Earth’s crust is subjected to depressions from the weight of continental glaciers, and the later rise of glaciers (Fader, 2005). The isostatic rebound caused raised shorelines to be formed and the depressions left from the glaciers raised the sea level by +45 m along the southern coast (Fader, 2005). Over the next five thousand years, the sea level dropped to –60 m, which caused erosion of glacial material and bedrock (Fader, 2005). The eroded materials were later reworked when the sea level rose to its present position 9500 years ago (Fader, 2005). The present characteristics of the Bay are from the high energy transgressive processes that coarsened and further eroded the seabed (Fader, 2005).

2.4 The Study Area: Grand Passage

Grand Passage is a water gap created by a fault offset within the North Mountain Basalt between Brier and Long Island (Canadian Seabed Research Ltd., 2014). The fault is interpreted as a strike-slip movement, with Brier Island being offset to the north (Canadian Seabed Research Ltd., 2014). The passage is 4.5 km long, is approximately 35 m deep. A small island, Peter’s Island, is located within the southern entrance, creating two channels (Canadian Seabed Research Ltd., 2014).

This passage was the focus of this study due to the presence of dune formations in the channel to the east of Peter’s Island (Figure 1.2). It is unknown whether the dunes are static or mobile. From previous studies done in Grand Passage, the geology dominantly consists of glacial till and gravel/sand which overlays the North Mountain Basalt bedrock (Figure 2.3) (Canadian Seabed Research Ltd., 2014). For the region offshore where the dune formations are present, the geology consists mainly of glacial till and gravel-cobble grains (Canadian Seabed Research Ltd., 2014). Further information of the bottom sediments will be gathered to further interpret the dune formations within this paper.

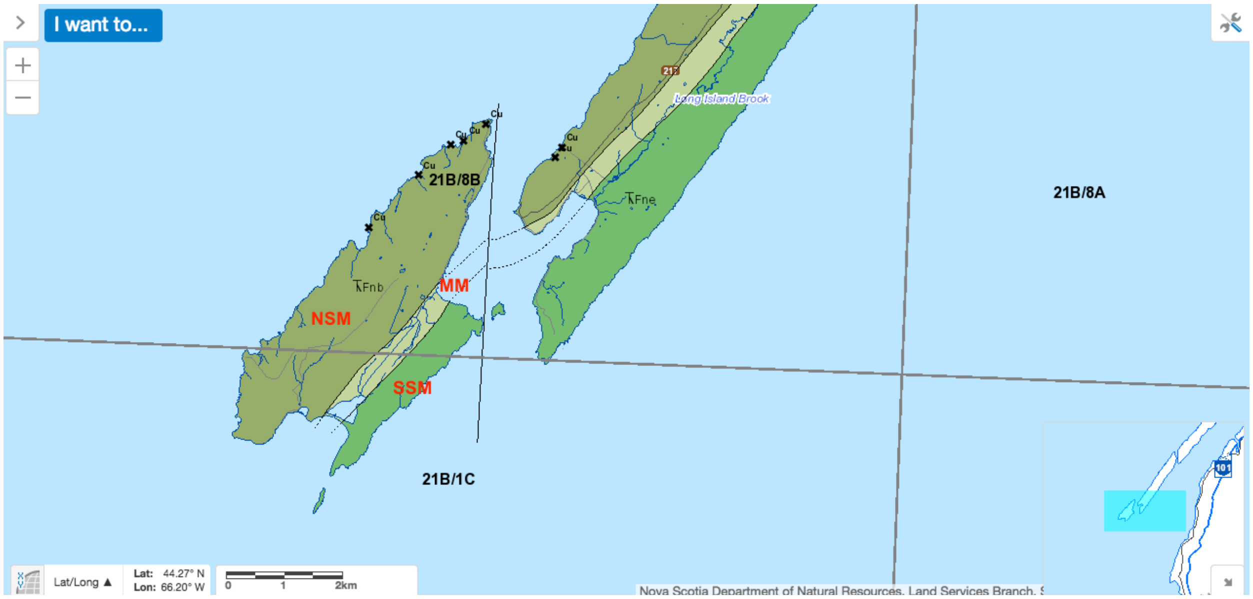


Figure 2.1: Geological map indicating the three units within the North Mountain Basalt; North Shore member (NSM), Middle member (MM), and South Shore member (SSM) (Interactive map, 2015).

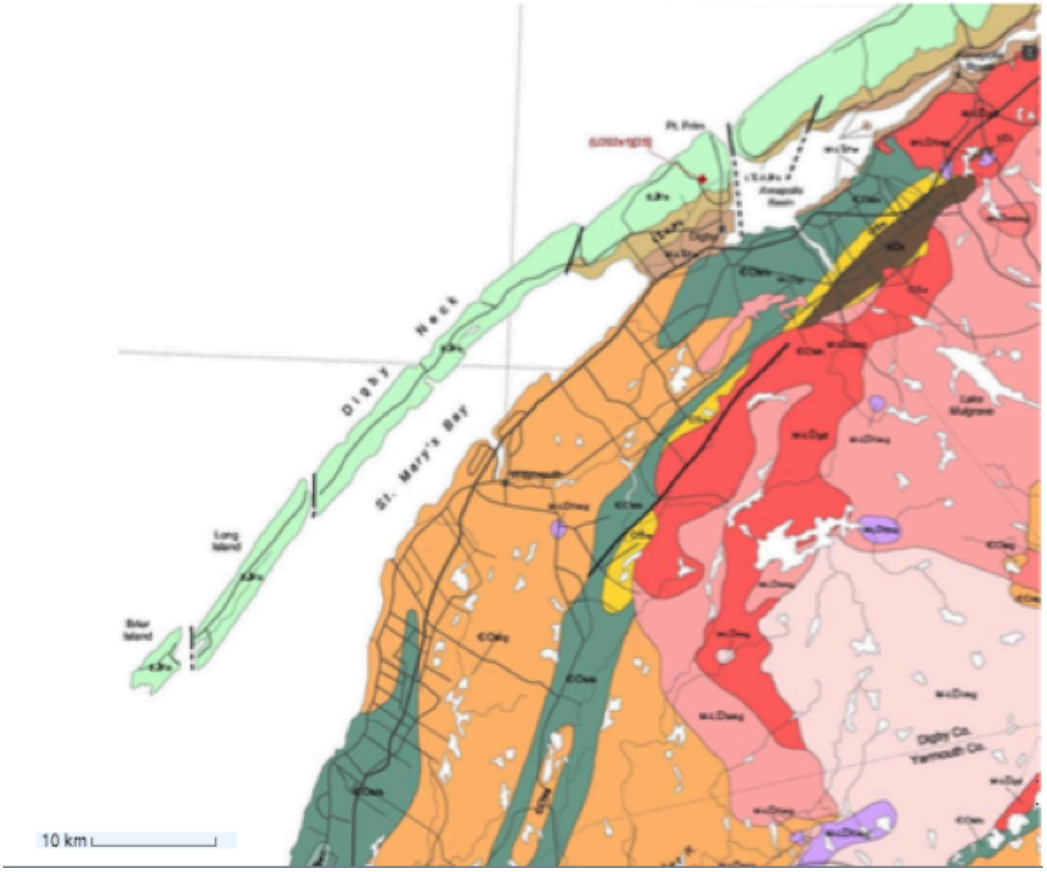


Figure 2.2: Geological map showing the faults along Digby Neck, Nova Scotia (Canadian Seabed Research Ltd., 2014).

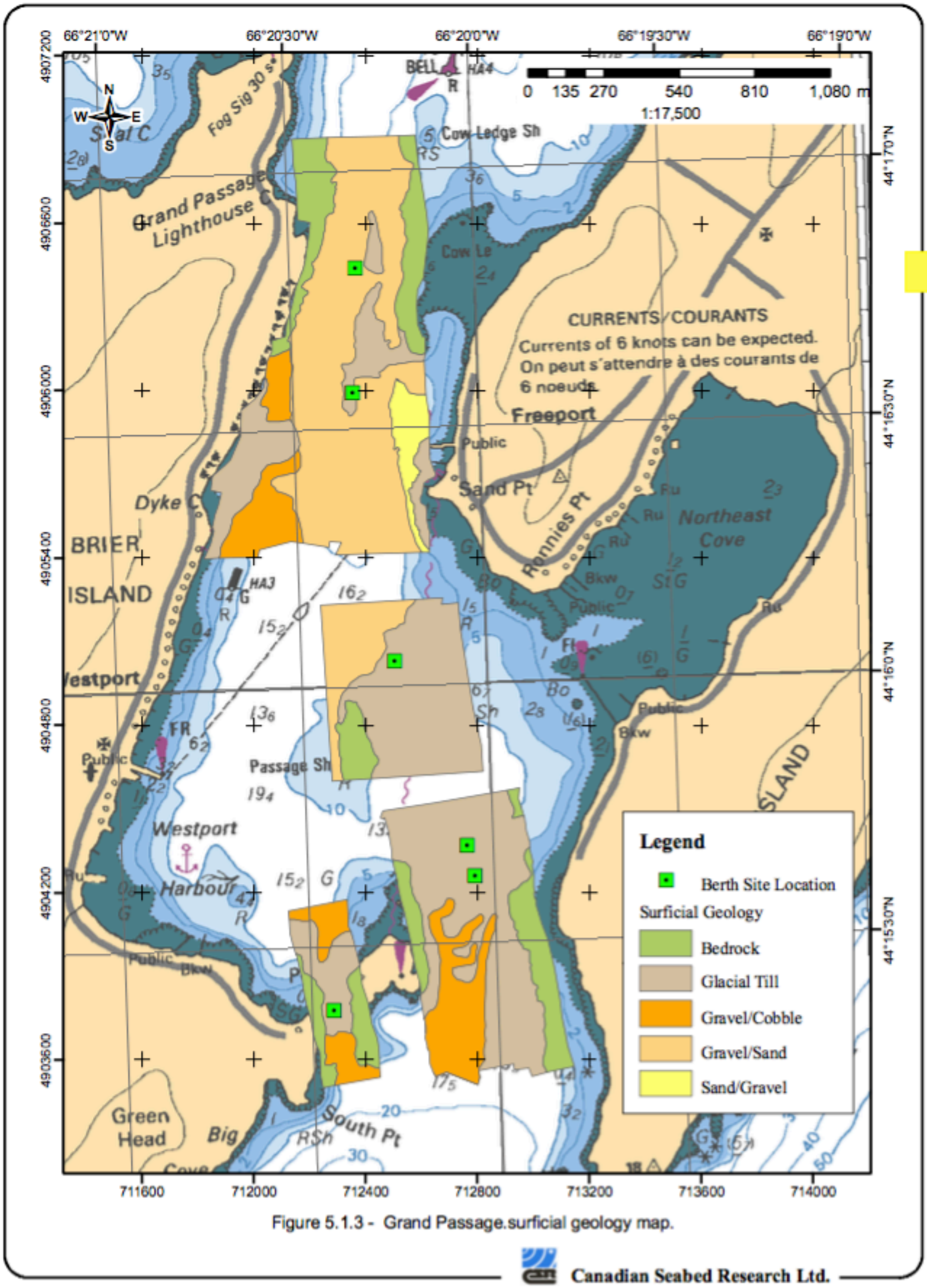


Figure 2.3: Surficial geology of Grand Passage around Peter's Island (Canadian Seabed Research Ltd., 2014).

CHAPTER 3: METHODS

3.1 Preparation

Before heading to the field, an instrument to hold and provide scale for the GoPro video footage had to be constructed (Figure 3.1). PVC piping was cut to form a rectangular frame with dimensions of 1 m by 1 m by 1.32 m and glued together using PVC solvent cement. An "X" shape, made of PVC pipe, was added into the top portion of the frame (Figure 3.2), while the bottom portion contained only the four sides. To help the frame sink when introduced to water, two shackles and two dive weights equaling a total of 8 lb., were attached to the base of the frame. Small, spaced apart, drill holes were also made in the PVC pipes to allow for water to drain from the frame.

Before the GoPros were placed onto the frame, the settings of both cameras were made identical to ensure that they would capture footage with the same frame rate, resolution, and field of view. The first GoPro was placed in the center of the "X" formed PVC pipe on a flat piece of plastic containing square holes. The GoPro was strapped onto the flat piece of plastic with zip ties so that the entire base of the frame could be seen within the video footage. The second GoPro was placed and zip tied to the joint between the "X" and the sidepiece of the top portion of the frame. The GoPro was then angled so that it would capture one full length of the base frame and observe more of the channel bed. The GoPro was angled this way so that a sense of orientation may be easier to observe when viewing the video footage. Two Mini Q40 dive lights that had small opaque Nalgene bottles taped onto the head of the light were attached beside each GoPro to provide light while at depth.

Finally, the GPS coordinates, which would be given to Captain Beau Gillis on the boat *School of Fish*, were recorded. The GPS coordinates were taken around the beginning and end of the dune formations around Peter's Island. Although the frame would not enter and exit the water at the exact beginning and end coordinate points, it was important to note where the dunes were for the boat to set course. The coordinates began north of Peter's Island (44°15.559 N, 066°20.101 W) and end south of Peter's Island (44°15.339 N, 066°20.111 W).

3.2 Field Work

In the field, rope bridle was attached to the four corners at the top of the frame that attached to the lowering rope. The GoPros were turned on before the deployment of the frame off the side of the boat *School of Fish*. The frame was lowered into the water over the side of the boat and allowed to sink to the bottom while the rope was paid out. Using a Garmin GPS, the vessel's position was recorded to keep a record of the time and placement of the frame while the boat drifted. Upon reaching the southern part of Peter's Island, the frame was returned back onto the boat deck. This process was repeated four times during ebb tide, each time beginning north of Peter's Island.

During the first trial, the frame was knocked to the side upon making contact with the bottom of the channel. The frame was lifted back up, adjusted, and returned to the bottom during the same trial. During the third trial, the frame was again brought up and lowered a second time during the same trial as well.

3.3 Retrieving Data

Once the video footage is collected, the time of each video and the GPS coordinates must be related. By converting the time of video capture to real time, the closest possible GPS coordinate can be correlated to the video using the Garmin GPS track record (Table 4.1 and Table 4.2). The same process can be done for the video stills, taken using the software GoPro Studio (Version 2.5.10.5365), from the video footage (Table 4.3 and Table 4.4). With these GPS coordinates, a path can be created in Google Earth to show where the frame was along the channel bed and where the bottom can be observed (Figure 4.1). For the stills, the GPS coordinates are overlaid onto a bathymetry map of Grand Passage, allowing the dunes and stills location to be observed (Figure 4.3).

The stills from the video footage used for analysis are taken at different points along the bed where a change in apparent grain size was observed. The stills were corrected for the distortion caused by the fisheye lens before proceeding further with analysis. A flat checkerboard was filmed in a tank of water using the same GoPro used in the field (Bouguet, 2015). The checkerboard was rotated within the tank to capture video footage of the board at different angles (Bouguet, 2015). Using Matlab (Version R2016b, 9.1.0.441655) and instructions from the website *Camera Calibration Toolbox for Matlab* (Bouguet, 2015) the video stills from the field can have the fisheye effect removed.

Using the 1 x 1 meter base of the frame for scale, the average grain size diameter can be determined for the grains in the images (Table 4.5). Using the Wentworth scale (Figure 3.3), the average grain size type was determined by the average diameter of the sediments found (Table 4.5). A mobility curve (Figure 3.4) was used to calculate whether or not the sediments on the channel bed would be mobile or static (Sumer & Fredsoe, 2002). The mobility curve depends upon the Shields parameter (Equation 1) and grain Reynolds number (Equation 2).

$$\Theta = \frac{U_f^2}{g(s-1)d} \qquad \text{(Equation 1)}$$

$$\mathrm{R} = \frac{d * U_f}{v} \qquad \text{(Equation 2)}$$

where Θ is the Shields parameter, R is Reynolds number, U_f is the bed shear velocity, g is the acceleration due to gravity (9.81 m/s^2), s is the specific gravity of the sediment grains (2.7), d is the grain size, and v is the viscosity of water ($1.2 \times 10^{-6}\ m^2/s$) (Sumer & Fredsoe, 2002). To solve for the bed shear velocity, the drag coefficient, C_D = 0.041, and the flow speed, U = 2.2 m/s (A. Hay, personal communication, March 2017), are used (Equation 3) (Sumer & Fredsoe, 2002).

$$U_f = \sqrt{C_D} * U \qquad \text{(Equation 3)}$$

The final determination of whether the sediment grains are mobile or static comes from the comparison of the calculated values of the critical Shields parameter and Reynolds number to the mobility curve critical shear stress, θ_{cr}, line presented in Figure 3.4.

Figure 3.1: Finished instrument, cuboid frame, used in the field (Besseau, 2016).

Figure 3.2: Top view of the frame being lowered into Grand Passage (Besseau, 2017).

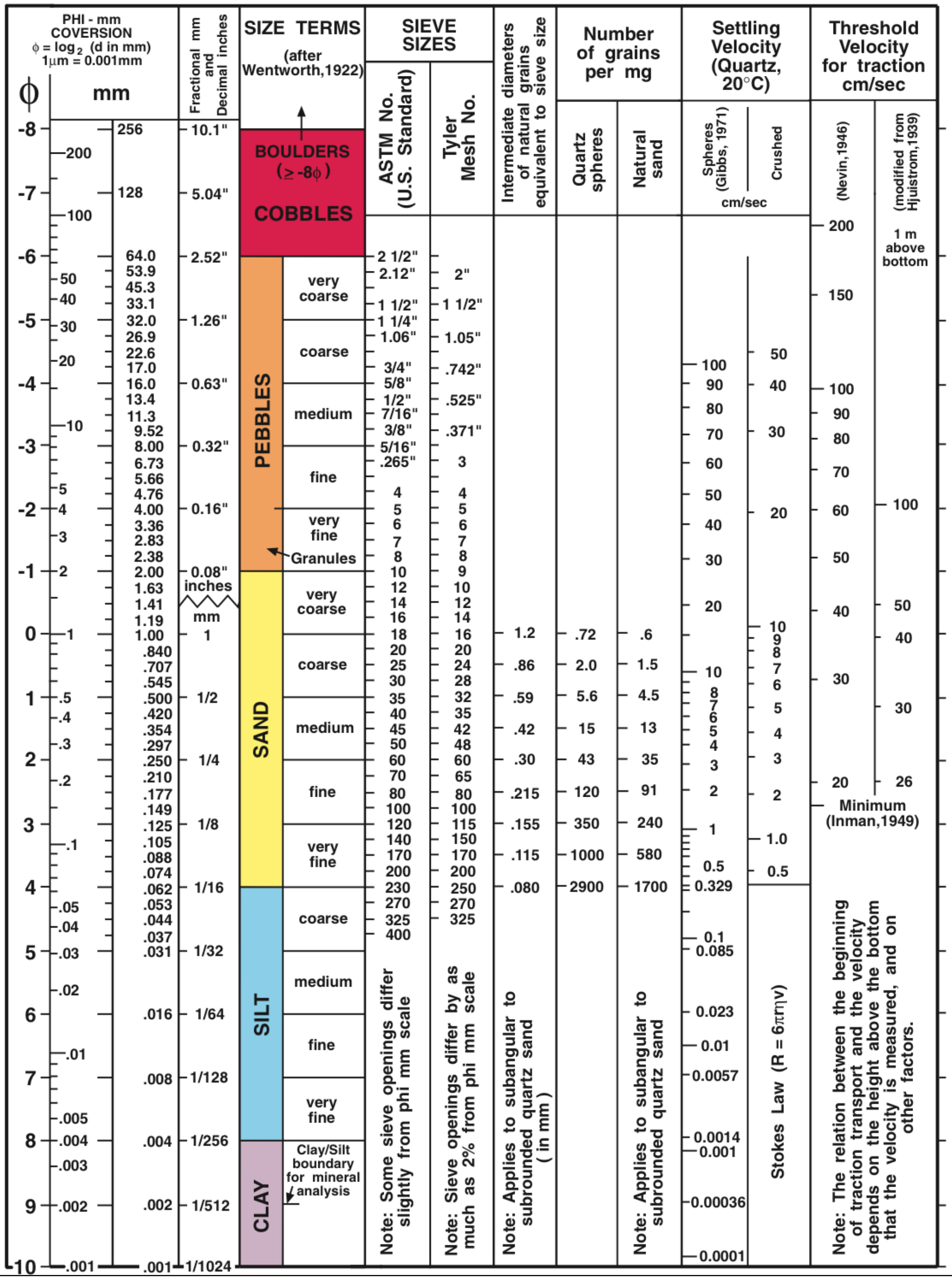


Figure 3.3: Wentworth scale used to determine grain size (Wentworth, 1922)

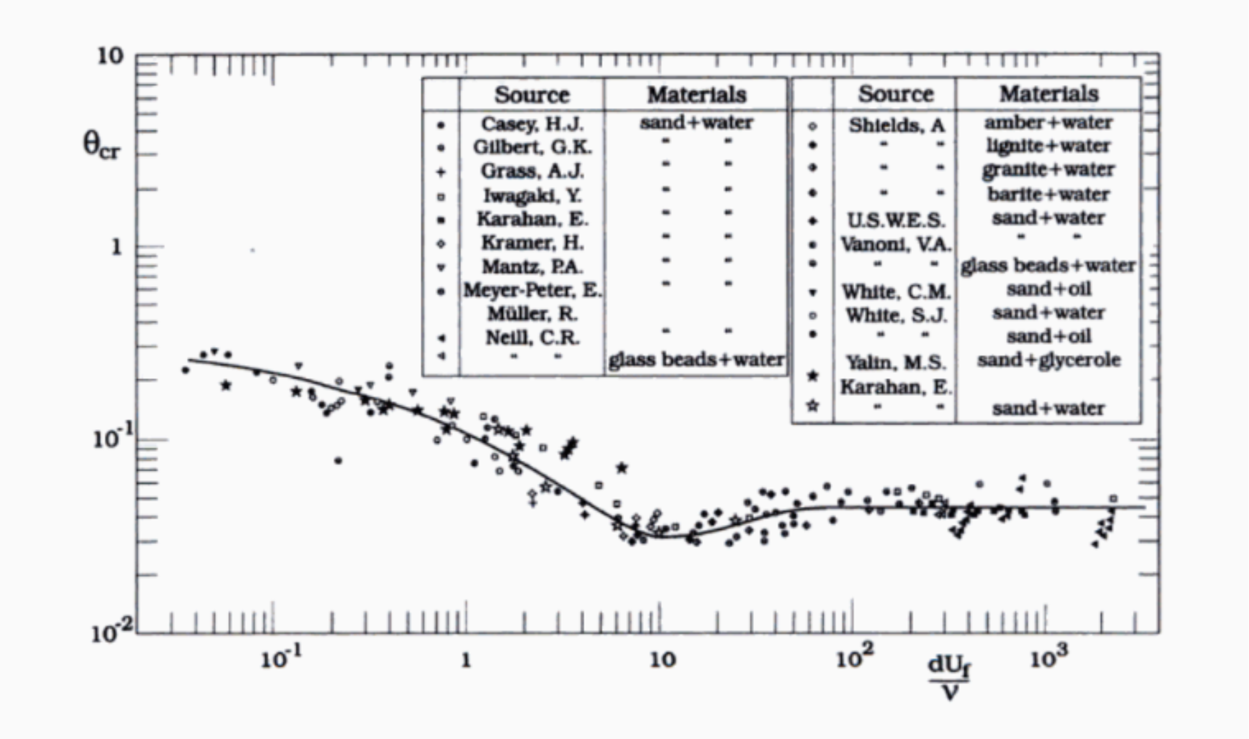


Figure 3.4: Mobility curve showing the curve of initiation of motion at the bed (Sumer & Fredsoe, 2002)

CHAPTER 4: RESULTS

Four trials beginning and ending around the coordinates 44°15.559 N, 066°20.101 W and 44°15.339 N, 066°20.111 W were conducted. However, video footage was usable from only the first and fourth trial video footage. The bottom of the channel was not observed in the other trials due to poor lighting or the frame was not close enough to the bottom.

Using the Garmin GPS track record, the GPS coordinates that correspond to the real time of the video footage can be determined (Table 4.1 and Table 4.2). After the collection of coordinates, a map with path lines indicating when the channel bottom can be observed in the footage is created (Figure 4.1).

TRIAL 1	
Real Time (Hour, minute, second)	**GPS coordinates (Latitude, Longitude)**
12:48:00	N 44°15.541, W 66°20.085
12:49:21	N 44°15.547, W 66°20.099
12:49:41	N 44°15.533, W 66°20.093
12:51:00	N 44°15.519, W 66°20.093
12:51:02	N 44°15.495, W 66°20.089
12:53:05	N 44°15.435, W 66°20.077
12:54:15	N 44°15.401, W 66°20.080
12:54:42	N 44°15.391, W 66°20.081
12:55:32	N 44°15.367, W 66°20.087
12:56:00	N 44°15.352, W 66°20.093
12:56:32	N 44°15.345, W 66°20.096

Table 4.1: Time and placement of frame retrieved from GPS track data for Trial 1

TRIAL 4	
Real Time **(Hour, minute, second)**	**GPS coordinates** **(Latitude, Longitude)**
15:41:29	N 44°15.566, W 66°20.096
15:42:24	N 44°15.507, W 66°20.067
15:42:94	N 44°15.443, W 66°20.052
15:43:10	N 44°15.425, W 66°20.050
15:43:16	N 44°15.406, W 66°20.042
15:43:36	N 44°15.388, W 66°20.040
15:43:45	N 44°15.366, W 66°20.041
15:45:28	N 44°15.247, W 66°20.052

Table 4.2: Time and placement of frame retrieved from GPS track data for Trial 4

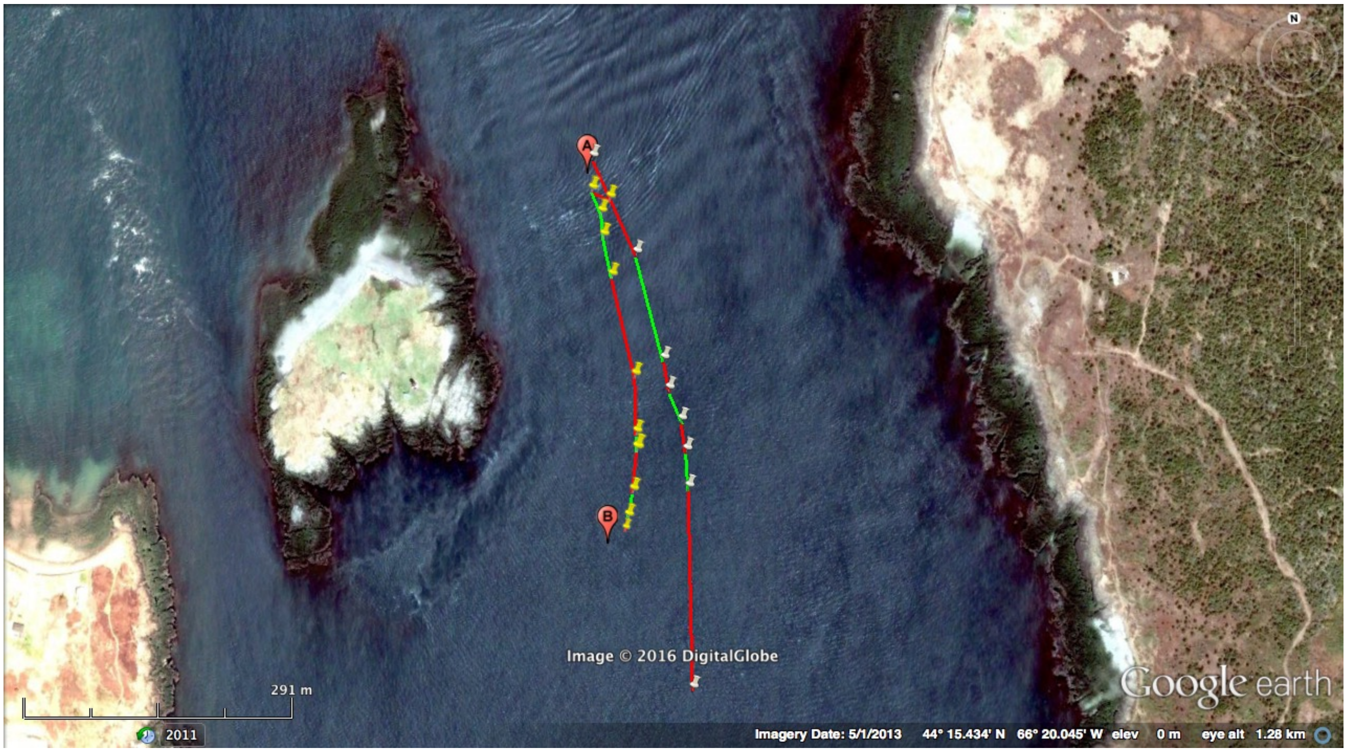
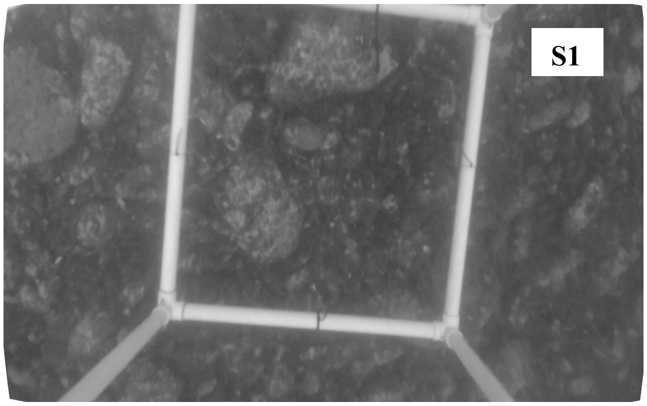


Figure 4.1: Path lines of Trial 1 (indicated along yellow place marks) and Trial 4 (indicated along white place marks). Green lines indicate when the channel bottom can be observed; red lines indicated when no footage of the bottom can be seen. (Google Earth, 2015).

The still images from the video footage were captured for different points along the bed where a change in apparent grain size can be observed. Before determining the grain size, using the Wentworth scale (Figure 3.3), the fisheye lens effect is removed from the stills in Matlab (Version R2016b, 9.1.0.441655) by following the instructions on the website website *Camera Calibration Toolbox for Matlab* (Bouguet, 2015). Stills S1-S11 correspond to Trial 1 and stills S12-S19 correspond to Trial 4 (Figure 4.2).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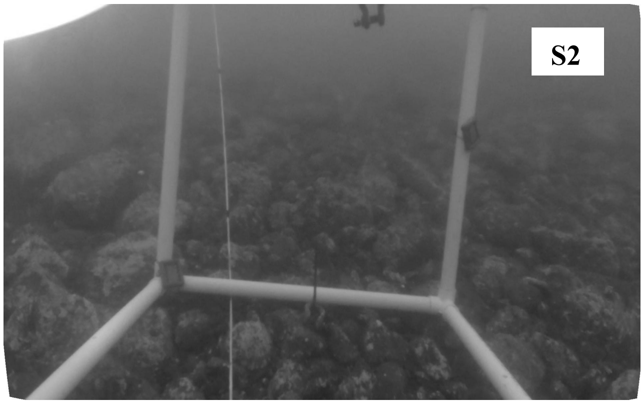
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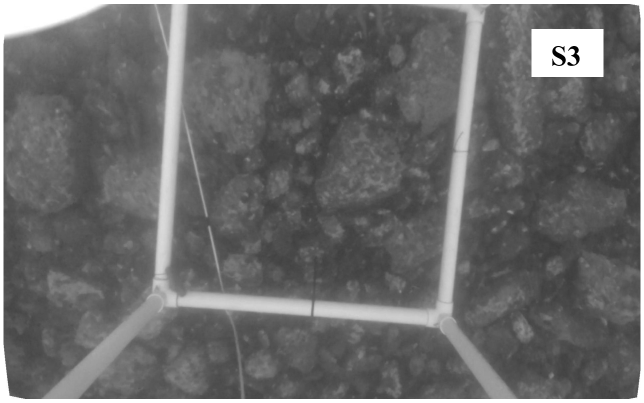
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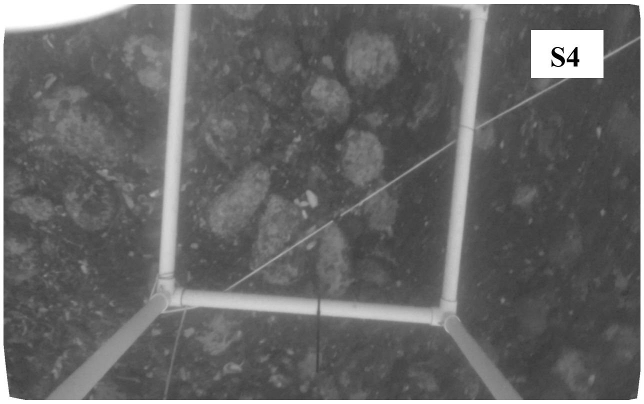
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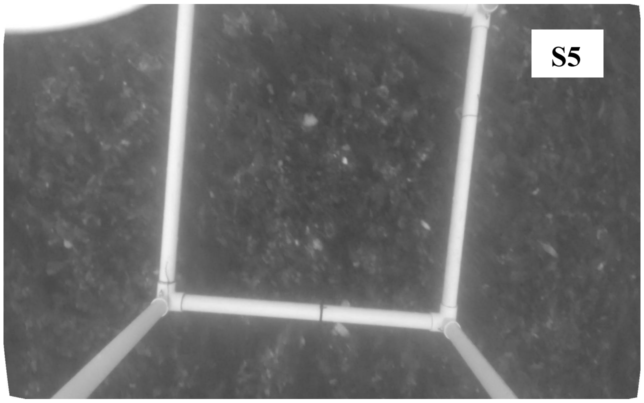
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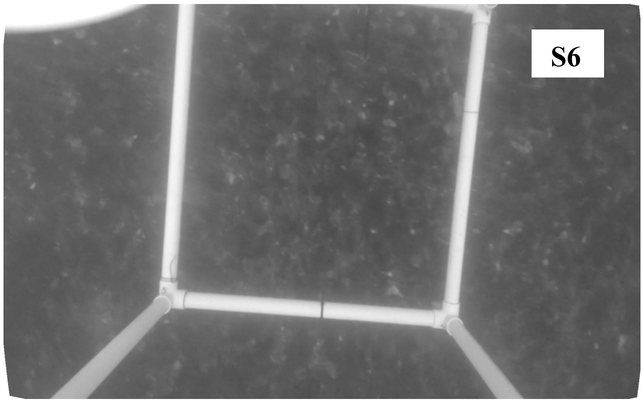
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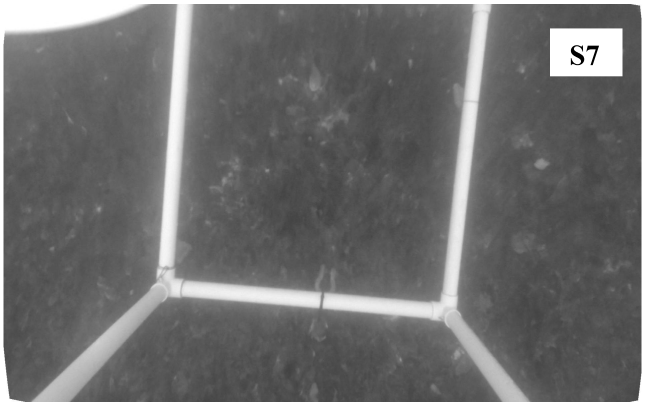
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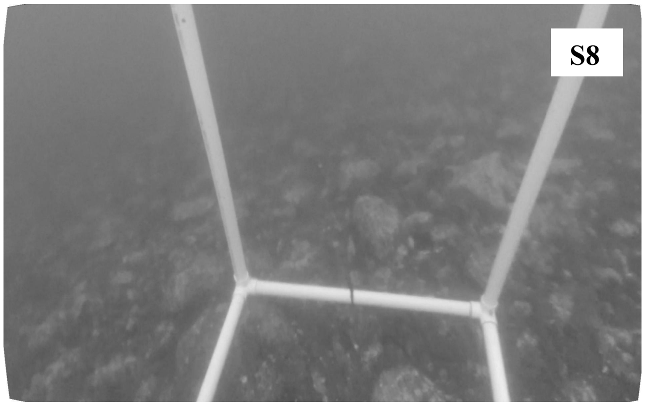
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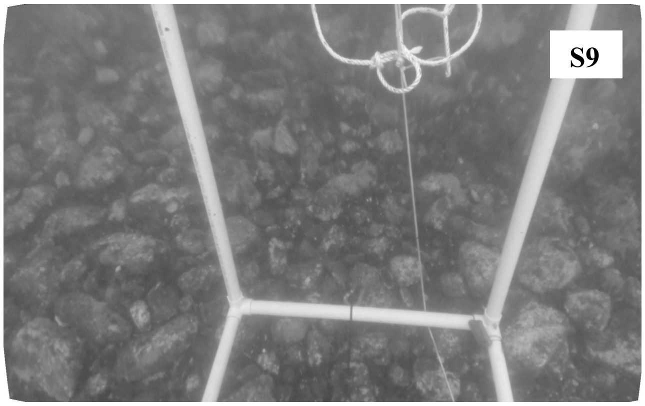
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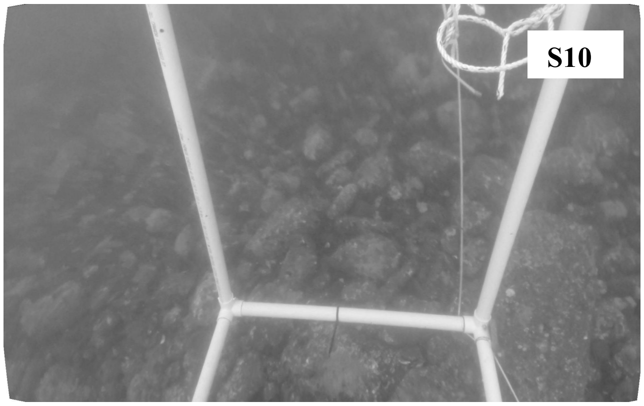
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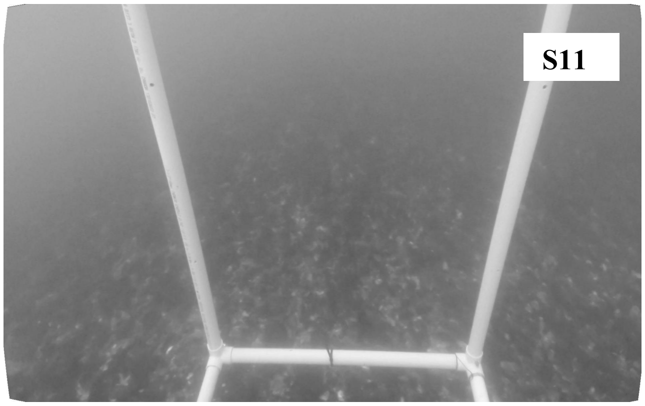
S11

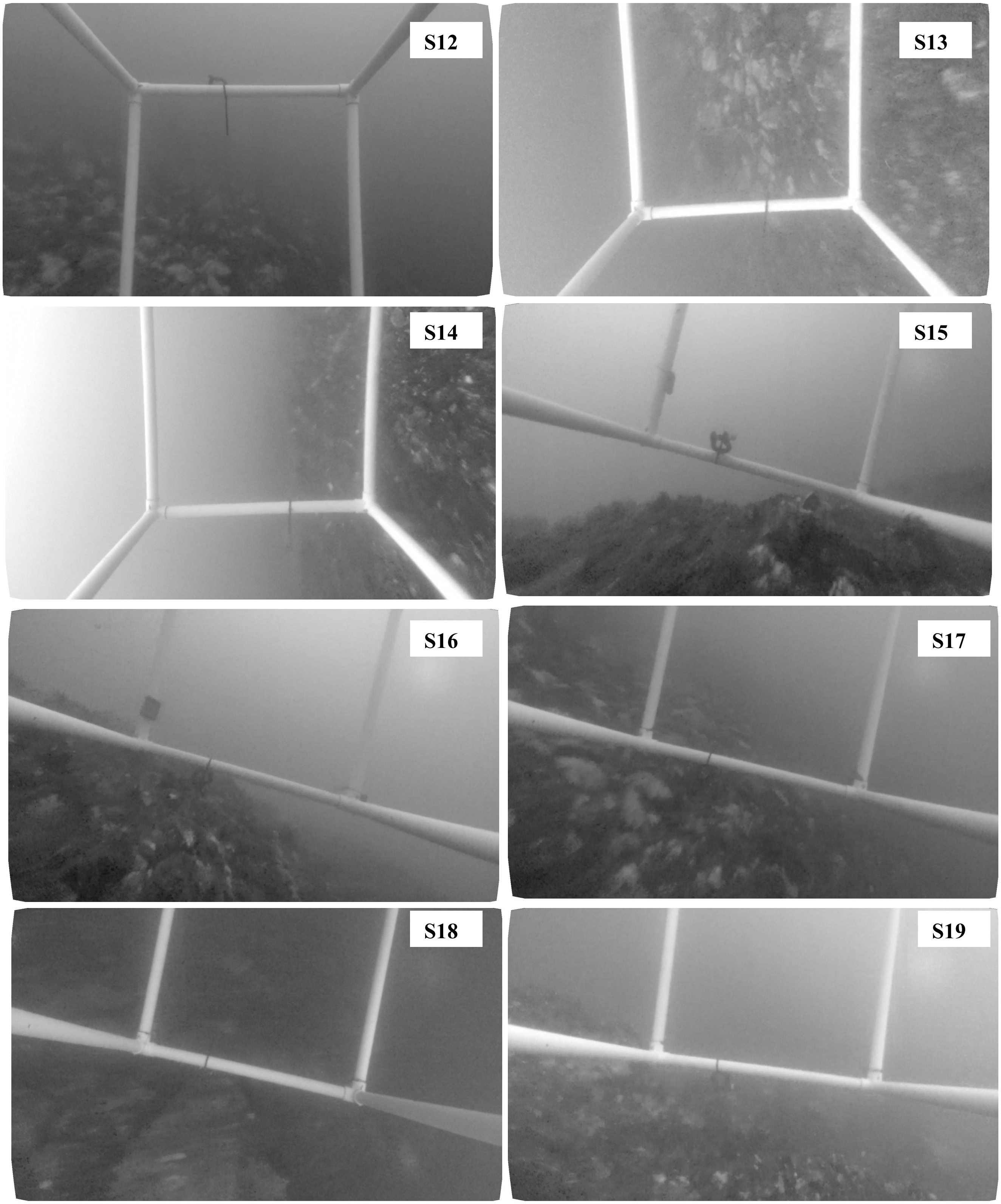

Figure 4.2: Collection of still images after fisheye lens effect is removed, S1-S11 corresponds to Trial 1 and S12-S19 corresponds to Trial 4.

For each still, the Garmin GPS track record can be used to find the corresponding GPS coordinates for the still images (Table 4.3 and Table 4.4). The still locations can be overlaid onto the bathymetry map (Figure 1.3) to see the relationship between average grain size and dune formation (Figure 4.3).

TRIAL 1: Still Image Information

Still ID	GoPro Placement	Real Time (Hour, minute, second)	GPS Coordinates (Latitude, Longitude)
S1	Middle	12:49:20	N 44°15.547, W 66°20.099
S2	Middle	12:49:41	N 44°15.533, W 66°20.093
S3	Middle	12:50:00	N 44°15.525, W 66°20.093
S4	Middle	12:51:00	N 44°15.495, W 66°20.089
S5	Middle	12:54:17	N 44°15.401, W 66°20.080
S6	Middle	12:54:30	N 44°15.396, W 66°20.080
S7	Middle	12:56:00	N 44°15.356, W 66°20.091
S8	Side	12:50:26	N 44°15.511, W 66°20.092
S9	Side	12:40:48	N 44°15.505, W 66°20.092
S10	Side	12:51:07	N 44°15.500, W 66°20.091
S11	Side	12:55:39	N 44°15.367, W 66°20.087

Table 4.3: Converted time of still image from video to real time, with found GPS coordinates from GPS track data. For GoPro placement, "middle" refers to placement of camera in the center of the "X" PVC pipe formation while "side" refers to the camera being placed on a side PVC pipe at the top of the frame.

TRIAL 4: Still Image Information

Still ID	GoPro Placement	Real Time (Hour, minute, second)	GPS Coordinates (Latitude, Longitude)
S12	Middle	15:42:48	N 44°15.461, W 66°20.054
S13	Middle	15:43:10	N 44°15.443, W 66°20.052
S14	Middle	15:43:39	N 44°15.388, W 66°20.040
S15	Side	15:42:30	N 44°15.507, W 66°20.067
S16	Side	15:42:30	N 44°15.507, W 66°20.067
S17	Side	15:42:43	N 44°15.483, W 66°20.060
S18	Side	15:43:05	N 44°15.443, W 66°20.052
S19	Side	15:43:25	N 44°15.406, W 66°20.042

Table 4.4: Converted time of still image from video to real time, with found GPS coordinates from GPS track data. For GoPro placement, "middle" refers to placement of camera in the center of the "X" PVC pipe formation while "side" refers to the camera being placed on a side PVC pipe at the top of the frame.

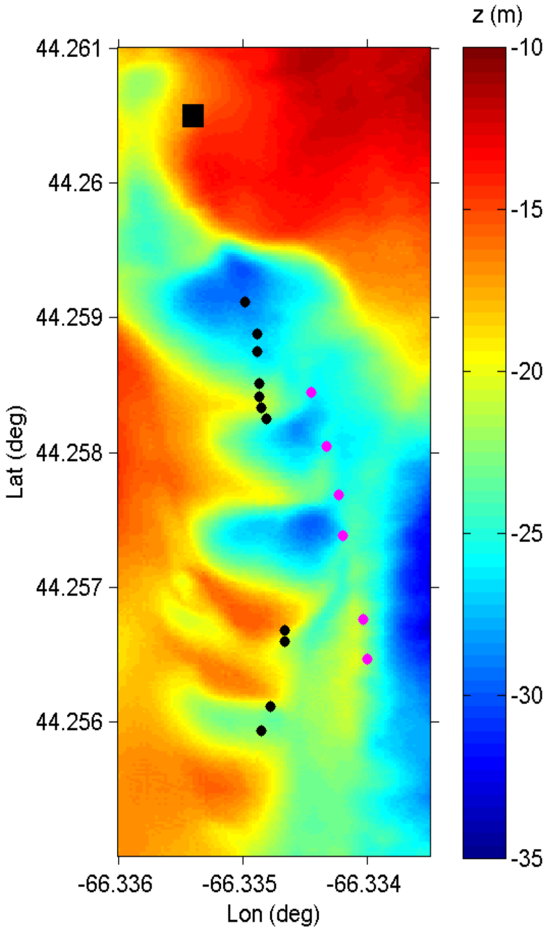

Figure 4.3: Bathymetry map showing the dune formations in Grand Passage with the markers for the stills taken along Trial 1 (black dots) and Trial 4 (purple dots). The black square is the ADCP location closest to the dunes, from which flow velocity is obtained. (A. Hay, personal communication, March 2017).

The average grain size diameter and average grain size, based on the Wentworth scale, can be determined and used to calculate the mobility curve parameters: Shields parameter (Equation 1) and the Reynolds number (Equation 2). Comparing the calculated values to the mobility curve critical Shields parameter, θ_{cr} (Figure 4.4), whether the sediments are mobile or static can be determined (Table 4.5) (Sumer & Fredsoe, 2002).

Mobility Curve Parameters and Results					
Still ID	**Average Grain Size Diameter (m)**	**Shields Parameter**	**Reynolds Number**	**Mobile or Static**	**Grain Size (Wentworth)**
S1	0.2208	0.054	81965.8	STATIC	Cobbles
S2	0.2512	0.047	93250.9	STATIC	Cobbles
S3	0.248	0.048	92063.0	STATIC	Cobbles
S4	0.1936	0.061	71868.5	STATIC	Cobbles
S5	0.0667	0.178	24760.5	MOBILE	Cobbles
S6	0.0608	0.196	22570.3	MOBILE	Very Coarse Pebbles
S7	0.072	0.165	26728.0	MOBILE	Cobbles
S8	0.1496	0.080	55534.8	MOBILE	Cobbles
S9	0.2176	0.055	80777.8	STATIC	Cobbles
S10	0.212	0.056	78699.0	STATIC	Cobbles
S11	0.0307	0.388	11396.5	MOBILE	Very Coarse Pebbles
S12	0.0864	0.138	32073.6	MOBILE	Cobbles
S13	0.0952	0.125	35340.3	MOBILE	Cobbles
S14	0.048	0.248	17818.6	MOBILE	Very Coarse Pebbles
S15	0.1168	0.102	43358.7	MOBILE	Cobbles
S16	0.0976	0.122	36231.2	MOBILE	Cobbles
S17	0.1112	0.107	41279.9	MOBILE	Cobbles
S18	0.368	0.032	136609.6	STATIC	Boulders
S19	0.0592	0.201	21976.3	MOBILE	Very Coarse Pebbles

Table 4.5: Mobility curve data and whether or not the location of the grains at a certain still is mobile or static.

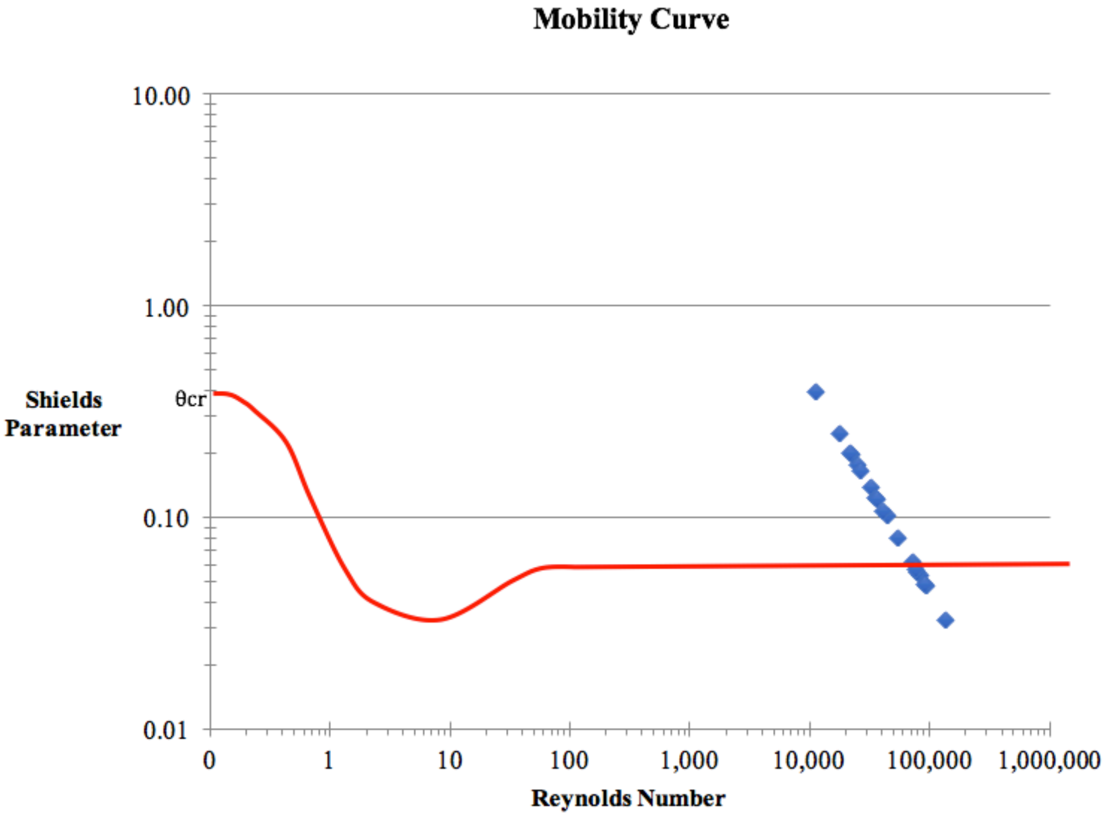

Figure 4.4: Mobility curve indicating where still shields parameters align with respect to the critical shields parameter value (Sumer & Fredsoe, 2002).

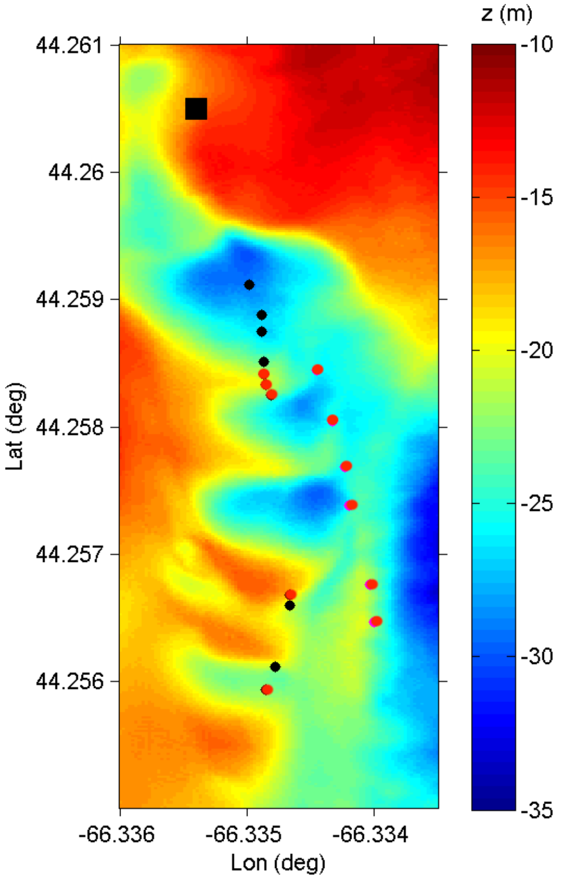

Figure 4.5: Bathymetry map showing the still images positions and the still locations indicated by the mobility curve to be mobile (highlighted in red).

CHAPTER 5: DISCUSSION

The data collected from Trial 1 and Trial 4 allow almost the entire channel bottom to be observed in the video footage (Figure 4.1). The series of still images show that the apparent grain size in certain regions of the passage change between cobbles, very coarse pebbles, and boulders (Figure 4.2). The locations of where the apparent grain size changes occur could, in future research projects, provide better understanding of what is occurring at depth along the dune formation (Figure 4.3). From the stills, the average grain size based on the Wentworth scale is found to be mainly cobbles (64 – 256 mm). On almost all of the still images, biological material is observed on and between the cobble grains. Biological material does not grow in regions of high activity, so the presence of such material on the cobbles in the passage indicate a lack of movement on the dunes. Biological material, such as algae and mussel shell fragments, are evident in stills S15 and S16.

Using the mobility curve, the Shields parameter, Θ, and grain Reynolds number, R, are used to calculate whether or not the sediment grains are mobile. The Reynolds number calculated based on the average grain size diameter in each still, fell on values that are past what is recorded on the mobility curve given (Figure 3.4). When the locations of each still's mobility curve parameters are located, many of the values align below the mobility curve critical Shields parameter, θ_{cr} (Figure 4.4). When the points fall below the critical line ($\theta < \theta_{cr}$) it indicates that there is no sediment motion, while points that fall above the critical line ($\theta > \theta_{cr}$) indicate that there is sediment transport (Sumer & Fredsoe, 2002).

With the mobility curve calculation, it can be inferred that most of the dune formation is inactive besides the crests of the dune which are active. The location of the stills S5 – S8 and S11, taken from Trial 1, are observed to be on the crest regions of the dune formations (Figure 4.5). At the crest of the dunes, the Shields parameter shows these grain sizes to be greater than the critical Shields parameter, indicating active sediment transport (Figure 4.4). As well, the crests are closer to the surface of the water and the grains at the crest regions are noticeably smaller than the grains at further depth (Table 4.5). While the average grain size is still within the cobble size range, very coarse pebbles (32 – 64 mm) are only found in crest regions. With increasing depth, the average grain size increases and the mobility curve indicates that these grains are static. The stills from Trial 4 also indicate sediment transport, however they are closer to a known mega-flute that occurs in the passage (Canadian Seabed Research Ltd., 2014). Due to this, it is noted that there is sediment transport along the mega-flute formation in Grand Passage.

CHAPTER 6: CONCLUSIONS

Grand Passage is just one of three channels along Digby Neck in the Bay of Fundy (Fader, 2005). The powerful currents of the Bay are still shaping Digby Gut, Petit Passage, and Grand Passage. From this study it is concluded that, at least within Grand Passage, there is sufficient evidence to suggest that the crests of the submarine dunes could be mobile. The mobility of the dune comes from the cobble sized grains of sediment on the channel bed moving along the seafloor due to a flow speed of 2.2 m/s (A. Hay, personal communication, March 2017). Based upon calculated Shields parameters and grain Reynolds numbers, when the average grain size diameter in this region of Grand Passage is less than 0.1 meters, sediment transport can occur.

In addition to this study's findings, further investigation of average grain size should be conducted. An instrument with more weight should be deployed with the GoPro cameras, a larger source of light should be used when at depth, all video footage should be taken when the current speed is low to allow for slower boat speeds, and the instrument should be lowered in advance before coming upon the beginning of the dune formation coordinates. Further investigation would allow for a more complete record of the average grain size along the entire dune formation to be observed.

While not all of the video footage collected in this study was usable, the first trial was a success in determining whether or not the dune formation was mobile or static. The bottom of the channel was easily interpreted from the video footage and a clear image of what was occurring at depth could be inferred. In conclusion, the submarine dune formation in Grand Passage is most likely active along the crests of the dunes while inactive with increasing depth.

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