Cruise Control

To further the understanding of the comprehensive impacts of cruise ships on the city of Venice.

An Interactive Qualifying Project Report
WORCESTER POLYTECHNIC INSTITUTE

Submitted to:
Project Advisors:
Professor Fabio Carrera
Professor James Cocola

Submitted by:

Shane Bellingham

Cortney Davis

Chris O'Brien

Erin Saari

December 17, 2010

Email: ve10-ships@wpi.edu
Project Website: https://sites.google.com/site/ve10ships/

Acknowledgements

We would like to give our most sincere appreciation to the following individuals. Without their knowledge, kindness, and dedication, the successes of our project would never have been possible.

Professor Fabio Carrera - For all his constructive feedback and guidance throughout the course of the project.

Professor Jim Cocola - For all his excellent suggestions and always making himself available to answer our questions.

Marco Zanforlin - For always going out of his way to help us with anything we could ever ask for, but most importantly the little things we didn't ask for. None of our mobility or air pollution results would have been possible without his assistance.

Antonio Campagnol - For taking time out of his busy day to provide us with knowledge we wouldn't have found elsewhere and giving us assistance whenever we asked.

Jeff Blair – For graciously lending us two aethalometers and always being there to assist us whenever we needed help.

Luca Zaggia - For providing us with data and videos from ISMAR on the hydrodynamics of the canals.

Marco Nogara- For providing us with all the knowledge of cruise ship operations.

Abstract

The ultimate purpose of this project was to further the understanding of the comprehensive impacts, both positive and negative, of cruise ships on the city of Venice. This objective was accomplished by quantifying the vibrations produced by these vessels, qualitatively representing their hydrodynamic impact on the city's canals, measuring their particulate emissions and analyzing the disembarking passengers' modes of transportation. Most importantly, future collaboration was fostered between both Venetian and American environmental, oceanic, and mobility experts to carry on with these studies.

Executive Summary

There has been little research available to the public on the subject of cruise ships effects on the city of Venice. The institute of Marine Sciences in Italy (ISMAR) has completed a study involving the passing of cruise ships and the hydrodynamic effects on nearby canals. Their results indicated an increase in speed as these ships passed. They concluded that as a cruise ship passed the water was pulled out of the canals increasing the canal speed.

Past research was otherwise minimal or needed validation. There is no available data on the effects of the vibrations created by the ships on canal walls, nor are there any measurements of the strength of these vibrations. Data collection needed to begin on these vibration effects. The data provided by ISMAR was initially criticized, and needed validation. Specifically, measurements needed to be taken on the canal velocity and height changes in the canals due to the passing of cruise ships. Furthermore, evidence of this change in canal flow needed to be visually captured. Data on the particulate emissions produced by cruise ships does not exist to our knowledge. Measurements of the amount of particulates in the air around the cruise ships therefore needed to be gathered. Finally, the transportation choices passengers have after disembarking and their effectiveness needed to be assessed.

The ultimate goal of this project was to fill in any holes in past research. In particular, we quantified the vibrations felt across the city, analyzed the hydrodynamic effects on Venice's waterways, measured the particulate emissions produced around Venice's harbor, and documented the transportation choices of passengers disembarking cruise ships. All of this data was used to analyze the comprehensive effects of cruise ships on the city of Venice.

Our specific objectives were to study the impacts that cruise ships have on vibrations, hydrodynamics, air quality and mobility. Figure 1 outlines the areas of Venice in which these impacts were studied. An accelerometer was placed along the Giudecca Canal to measure vibrations while cruise ships passed or docked. The velocities and heights of canals along the Giudecca Canal were also measured using a meter stick and a flotation device. In addition an aethalometer was placed in Marittima to measure the amount of black carbon emitted from the cruise ships. The transportation choices of passengers were also studied by placing time lapse cameras and counting which mode people chose.

Figure 1: Area of Study

Vibrations

Cruise ships create vibrations as they pass along the Giudecca canal. Six measurements were completed although many more were attempted. Technical malfunctions involving the phone or the computer were frequently encountered. The measurements showed that there were vibrations created by a ship that is docking. However, vibrations for passing ships were not detected because the ship is further away from the shore and accelerometer. In conclusion, there are vibrations created by the engines of cruise ships, but the device was not sensitive enough to detect the vibrations from a passing ship.

The recommendation for next year is first to find a more sensitive device that will be able to detect the vibrations created by the ship. If a device can be acquired, the vibrations should be measured right along the Giudecca Canal as well as further into the city of Venice to see how far the vibrations from these ships are traveling.

Hydrodynamics

As cruise ships pass smaller canals along the St Mark's Basin and Giudecca Canal, they displace and accelerate the surrounding body of water, essentially pulling water from the smaller canals. This caused a noticeable increase in canal speed and a drop in the water levels. A total of five velocity tests were completed resulting in a 57.4% increase in canal speed, and two canal height tests were completed which showed an average water level drop of 11 centimeters. The observations suggest that the root cause for these accelerations can be explained by the Bernoulli Effect: the colossal geometry of cruise ships creates fast currents and low pressure areas around the moving vessels. Both visual (Figure 2) and quantitative support was provided for CNR-ISMAR's studies from 2003, concluding that their findings were accurate.

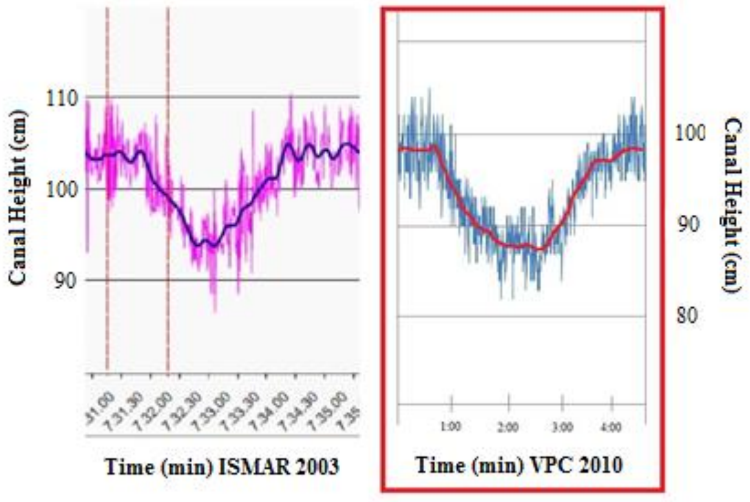

Figure 2: Side by Side Graphs for *European Vision* (left) and *MSC Magnifica* (right)

Make immediate contact with Mr. Luca Zaggia, a helpful collaborator from ISMAR. He has a plethora of knowledge pertaining to the hydrodynamics of large vessels traveling in the Venetian lagoon, both passenger and commercial. Also, the velocity device which was used was made for inner canals - not canals immediately connecting to the Giudecca Canal or Venetian Lagoon. The floatation device was not intended for such turbulent and unpredictable waters. More sophisticated measuring tools are also highly recommended. Consider finding sponsorships for, or otherwise securing pressure sensors that can be placed in the canals during cruise ship passing. A Venetian's greatest interest in this matter is not how much the water accelerates, but whether or not the cruise ships are causing damage to the canal walls.

Air Quality

The presence of cruise ships (and ferries) account for approximately a 4.5 times increase in BC in the city of Venice. The BC levels seem to be nearly the same in the Marittima as the rest of Venice. Also, the emissions from the smaller boats are much more pollutant than the emissions from the cruise ships and ferries. This is because the cruise ships are held to higher standards in terms of regulations on their emissions. Also, the aethalometer was much closer to the smaller boats' emissions than the cruise ships' and ferries' emissions. Although there is a significant increase in BC with the presence of cruise ships and ferries, the levels do not violate U.S. regulations on the permissible exposure limit to black carbon, which is 3.5 mg/m^3 TWA for OSHA.

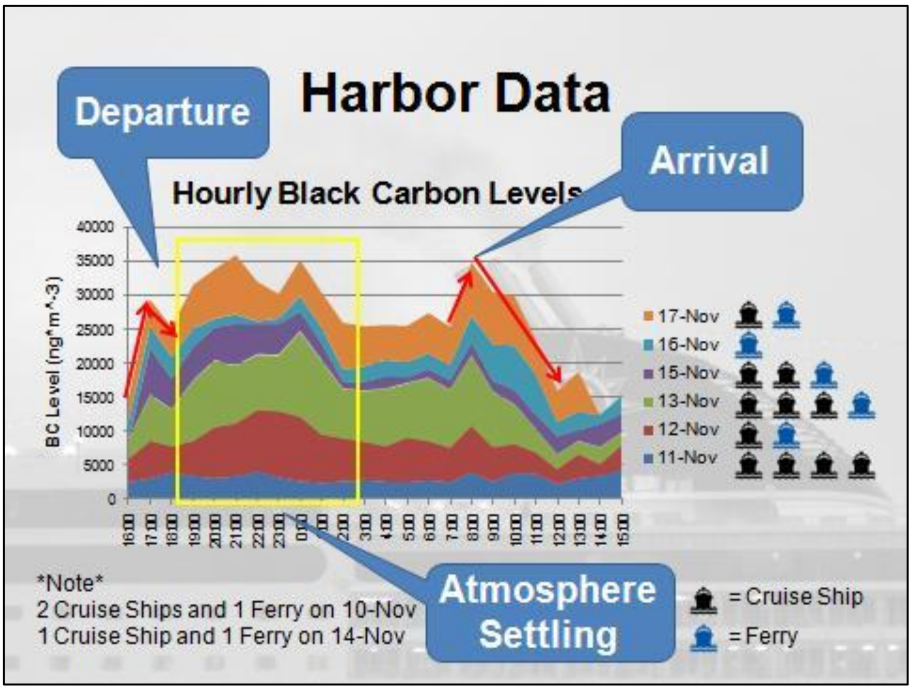

Figure 3: BC Level Comparison Graph

Jeff Blair, currently the CEO of Magee Scientific, should be contacted as early as possible to obtain an aethalometer to measure the black carbon produced by cruise ships. However, it is recommended that future groups incorporate the presence of ferries in their research as well. After getting in touch with Marco Zanforlin, future groups should contact Roberto Spinazze and Luisa Vianello from ARPAV. Collaboration efforts have already been made between the VTP, ARPAV and Magee Scientific. However, future groups should follow up on these efforts and further the collaboration.

Mobility

As cruise ships dock in Venice they can unload over 3,000 people at one time. Some days multiple ships can disperse over 13,000 passengers[1]. Measurements were completed to study the transportation choices of all these passengers. Five transportation options were considered: buses, boats, taxis, walking, and the new people mover. Measurements were taken over five days with fourteen ships and 15,438 people counted (Figure 4). The results indicated that buses were most popular with 39% (6,059) of the passengers choosing buses. This was likely of their low cost, location right outside the terminal, and their familiarity. The boats were the second most popular with 25% (3866) of the passengers choosing boats. The boats have the most destinations and are well advertized around the harbor. There were three different boat options: Alilaguna, tour boats, and water taxis. The Alilaguna lines were the most popular and had the most advertisement. The land taxis were also quite popular with 21% (3209) of the passengers choosing taxis. They were well labeled and familiar to many people. The last two modes of transportation are much less popular, only 9% (1386) chose the people mover and 6% (918) chose walking. The cold, rainy weather and lack of advertisement were contributing factors to their lack of popularity.

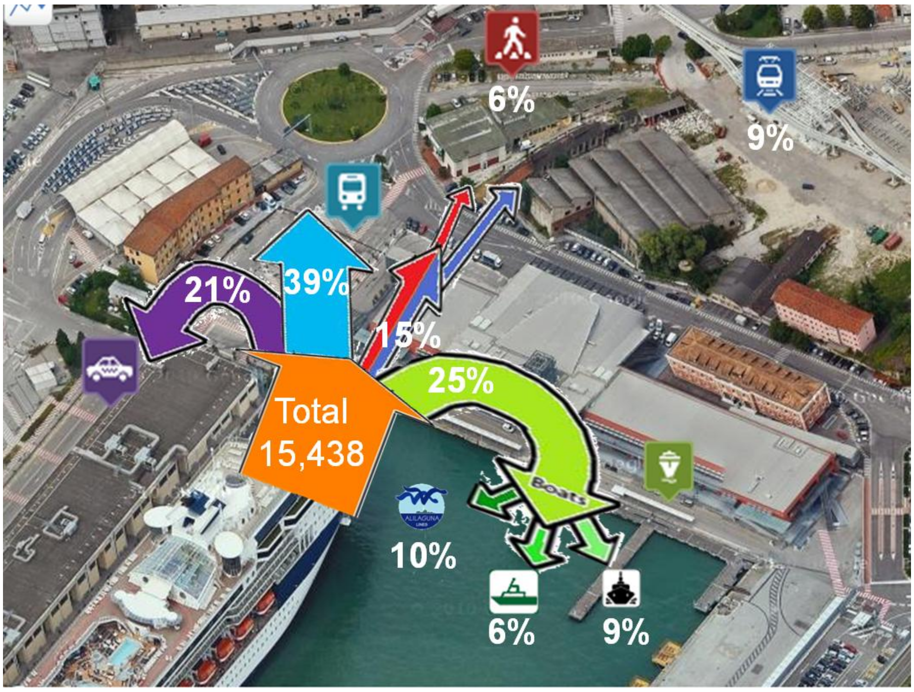

Figure 4: Mobility Results

[1] "Venice Terminal Passeggeri " http://www.vtp.it/calendario/ricerca.jsp?CercaNave=OK&password=null&CodNave=&CodArmatore=&Giorno=&Mese=&Anno (accessed 9/16/2010, 2010).

For mobility measurements contact with the harbor and Marco Zanforlin as soon as possible is crucial. Most of the field work will be done in the harbor so permission to enter needs to be granted as quickly as possible. A survey should be done on the nationality of the passengers and their transportation choices. It has been considered that more Italians walk than Americans and other nationalities because they know more about Venice and may know its layout according to the VTP.

To fully assess the impact cruise ships have on mobility where the passengers are going after they disembark needs to be determined. Many of the ships are turnaround so the passengers are often not going into the city of Venice but rather to the airport or the train station.

Overall Recommendations

With all the information collected this year there are many recommendations for future efforts. WPI students will encounter many limitations to their data collection, namely a given amount of cruise ship calls, manpower, and budget. Especially for students furthering these initiatives, it is crucial to plan accordingly. Become familiar with the background research and results outlined in this project summary.

For nearly all aspects of the project, contact with Marco Zanforlin early in the preparation will be compulsory. The end of October and the beginning of November are when the most cruise ships come, which means that only the first three or four weeks can be used for data collection. Plan to take measurements upon arrival; you don’t want to miss the busiest season of the year.

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1. Introduction

The Cruise Ship industry has increased dramatically throughout the world during the past 10 years. This massive increase could be leading to problems for the cities these ships visit. A subtle occurrence that people often overlook, are the vibrations caused by the cruise ships. Vibrations with small amplitudes, small periods and large accelerations have been found to deteriorate materials over time[2]. In addition, the wakes caused by these ships can have subtle impacts that may lead to structural damage over time. Concerns over the environmental impacts of cruise ships are a rather new development, first arising in the 1980s when laws were established limiting the amount of waste cruise ships are allowed to dump into the ocean[3]. Air pollution has become a growing concern over the last decade. The gases produced from the burning of the ships' fuel are some of the top-rated gases responsible for global warming. In 2000, commercial ships were responsible for 7% of nitrogen oxide (NOx) and 6% of particulate matter (PM) emissions in the United States. More people are realizing how leisurely and easy it is to travel from destination to destination on these floating cities. From 1998 to 2008 the number of people who took cruise ships each year doubled with a 222% increase to 13,005,000 people[4]. The destinations of these ships quickly become congested with the influx of people visiting, making it difficult for pedestrians to navigate their way around the area. These few statistics, among others demonstrate the importance of the topic and the need for an investigation into the impacts of cruise ships.

The city of Venice is one of the most popular destinations for tourists in the world. As the cruise ships travel through the narrow Giudecca canal they can have as little as 112 meters on either side of the ship and this waterway can be as shallow as 11 meters[5]. Vibrations have been found to cause significant negative effects on historic buildings[6]. In addition, the wakes created by these ships also have been found to speed up the flow and lower the height of the water in the canals[7]. The pollution created by these ships when they are entering through the Giudecca and sitting idling in the harbor could be negatively affecting the air quality. In 2010 there will be 574 cruise ships that dock in Venice carrying anywhere from 200 to 3,500 passengers; with the visits ranging from eight hours to three days. In a single day multiple cruise ships can bring in over 13,500 passengers. When this number is compared to the Venetian population of 60,000 it's over a 22% increase in the population[8]. With this amount of passengers disembarking throughout the day, the harbor can become congested. There are a variety of methods to transfer these crowds into the historic

[2] F. Schiappa de Azevedo, J. Patricio. "ANNOYANCE AND DAMAGE IN BUILDINGS CAUSED BY VIBRATIONS. CONSIDERATIONS FOR A VIBRATION CONTROL GOOD PRACTICE." *Acustica* 2010, no. 9/18/2010 (2004) (accessed 9/18/2010).
[3] Katsioloudis, Petros J. "Green Ships: Keeping Oceans Blue." *The Technology Teacher* 69, no. 5 (-02-01, 2010): 5-9.
[4] *2009 CLIA Cruise Market Overview* (accessed 9/18/2010).
[5] Davis, Robert. Marvin, Garry. *Venice: The Tourist Maze*. Berkeley: University of California Press , 2004
[6] F. Schiappa de Azevedo, J. Patricio. "ANNOYANCE AND DAMAGE IN BUILDINGS CAUSED BY VIBRATIONS. CONSIDERATIONS FOR A VIBRATION CONTROL GOOD PRACTICE." *Acustica* 2010, no. 9/18/2010 (2004) (accessed 9/18/2010).
[7] Skweirczynski, Hunnewell, Reese, Vautrin, "Cruise Ships: Influencing the City of Venice." (2010)
[8] "Venice Terminal Passeggeri " http://www.vtp.it/calendario/ricerca.jsp?CercaNave=OK&password=null&CodNave=&CodArmatore=&Giorno=&Mese=&Anno (accessed 9/16/2010, 2010).

city of Venice[9]. An analysis of the effects made by cruise ships on Venice needed to be completed.

Past research has been conducted by the institute of Marine Sciences in Italy (ISMAR). They obtained results supporting an increase in canal speed as these ships passed. They measured that as a cruise ship passed the water was pulled out of the canals increasing the canal speed.

Past research was minimal or needed to be validated. There is no available data on the effects of the vibrations created by the ships on canal walls, nor are there any measurements of the strength of these vibrations. Data collection needed to begin on these vibration effects. The data provided by ISMAR needed to be validated. More measurements needed to be done on the velocity change in the canals due to the passing of cruise ships. Evidence of this change in canal flow due to the passing of cruise ships needed to be visually captured. Data on the particulates produced by the cruise ships does not exist to our knowledge. Measurements of the amount of particulates in the air around the cruise ships needed to be gathered. The transportation choices passengers have after disembarking needed to be assessed and a study needed to occur on the effectiveness of these modes.

This project will be filling in all the holes that past research has created. This project focused on quantifying the vibrations felt across the city produced by cruise ships, and analyzing the hydrodynamic effects from transiting cruise ships on Venice's waterways. As well as measuring the particulate emissions produced by the cruise ships around Venice's harbor and documenting the transportation choices of passengers disembarking cruise ships. All this data that was collected will be used to analyze the effects of cruise ships on the city of Venice.

[9] "People Mover moves out (sort of)." Apr 22 2010.http://livingveniceblog.com/2010/04/22/peoplemover-moves-out-sort-of/ (accessed Sep 6 2010).

2. General Background

The cruise shipping industry is not new to the world or to Venice. The industry has been increasing over the years with more ships and many more people. This increase could have numerous effects, both positive and negative, on the places they visit.

To fully understand all the impacts, an understanding of the type of calls is necessary. There are two types of calls that a cruise ship can make to a city. There are transit calls, which are when the ship docks at a port, all the passengers travel around the destination for a day or more and then the passengers return to the ship to leave. A turnaround call is where the cruise starts and ends at a port. The passengers disembark in at that port at the end of their journey and can either go into the city or to the airport or train station. The ship remains in that port until new passengers embark.

These ships are economically beneficial to the communities they visit because of the vast number of tourist they bring in each year. It is estimated that at each port each transit passenger disembarking from a cruise ship will spend 57 Euros, and each turnaround passenger will spend 100 Euros[10]. With an average of 2500 people on each ship that is 142,500 Euros for each transit ship at each port and 250,000 for each turnaround ship at the homeport.

There are potential negative effects that cruise ships bring to the community it visits as well. The ships can cause detrimental effects to the structure and buildings of the city itself. The vibrations that are created by the massive engines of these ships could be causing deterioration of the communities' buildings particularly the historic ones. The hydrodynamics and wakes caused by the ships are another cause of the deterioration of the city, specifically the walls or banks that make up the waterways surrounding the city. These ships engines also produce a large amount of air particulates that could be causing health and safety problems for the people who live in these communities. The last negative effect that cruise ships can have on the city of Venice is the impact on mobility. On some days 13,000 or more people disembark from these ships[11] and make their way through the city and there is likely to be some congestion.

2.1 Cruise Ship Industry

The first luxury cruise, the *Prinzessin Victoria Luise*, set sail on January 5th, 1901 from Hamburg, Germany. This ship was designed for the wealthy to cruise the sea in luxury, specifically the Mediterranean. She was the first of many liners, most of which stemmed from the idea of making transatlantic trips more luxurious to compete for passengers[12]. Perhaps the most notorious example was the HMS *Titanic*, which offered opulent staterooms, architecture, and fine dining.

[10] Driving expansion ,Industry News | Cruise News, accessed 9/16/2010
[11] "Venice Terminal Passeggeri " http://www.vtp.it/calendario/ricerca.jsp?CercaNave=OK&password=null&CodNave=&CodArmatore=&Giorno=&Mese=&Anno (accessed 9/16/2010, 2010).
[12] *S/S Prinzessin Victoria Luise, Hamburg America Line*. (n.d.). Retrieved Dec 15, 2010, from Norway-Heritage: http://www.norwayheritage.com/p_ship.asp?sh=privl

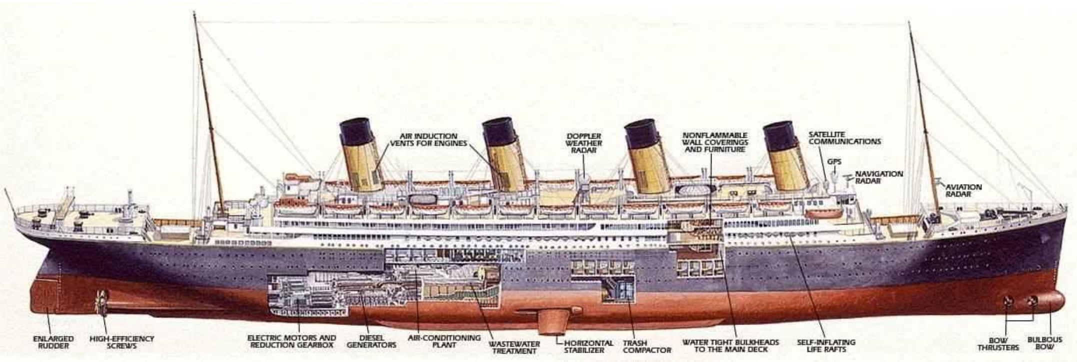

Figure 5: The HMS Titanic's Structure

The *Titanic*'s sinking in April, 1912 gave rise to several concerns regarding the sacrifice of seaworthiness for luxury. Regardless, these "mega-ships" continued as the leader in trans-oceanic transportation through the early twentieth century into the 1960's. During this time, the *Prinzessin Victoria Luise*'s designer, Albert Ballin, sent his luxury lines on much longer, southern transatlantic routes during the winter months. Avoiding the frigid weather and treacherous waters of the North Atlantic, Ballin set a new standard of luxury for his passengers.

The dominance of jet-propelled airliners in the 1960's (the "Jet Age") gave passengers the option to take a half-day flight with competitive prices over a five-day cruise[13]. During the ship's reign, the liners were built to maximize capacity in the stead of comfort. This new age sent the cruise ship industry into a slow decline for over 20 years.

Figure 6: MS *Majesty of the Seas*, an Early Sovereign-Class Cruise Ship

During the late 1980's, the building of contemporary Norwegian Sovereign-class cruise ships began a new era of cruise lines. Cruising became a vacation, and a pleasure rather than a necessity. The Sovereign-class (Figure 6) liners were the first to feature a multi-story atrium, glass elevators, and an entire deck of ocean-view verandas[14]. Since then, modern-era cruise ships were built with even more size, capacity, and amenities to offer the most enjoyable experience possible.

Since the first 400-passenger cruise in 1901 the industry has only grown. In 2010, the cruise ship industry is expected to account for US $26.8 billion and 18.4 million passengers

[13] Duke University Libraries: Digital Collections. "A Brief History of the Passenger Ship Industry." http://library.duke.edu/digitalcollections/adaccess/ship-history.html (accessed 11/21/10)

[14] Roughan, John. "The Ocean – Going Stretch Limo." http://www.nzherald.co.nz/queen-mary-2-giant-of-the-seas/news/article.cfm?c_id=1501162&objectid=10424244 (accessed 11/21/10).

worldwide[15]. From 1998 to 2008 the number of people who take cruise ships worldwide each year has increased by 222 percent[16] (Figure 7).

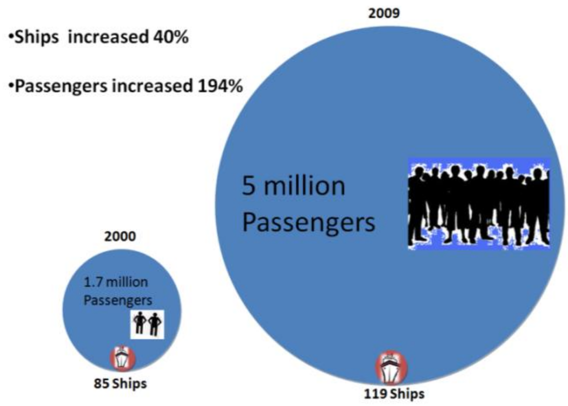

Figure 7: Cruise Ships are Getting Bigger: Ships vs. Passengers in Europe

The engine in a ship is the powerhouse. It not only supplies the energy for propulsion, but also for the ship's systems such as electricity. If a cruise ship is large enough it could have two separate engines; a main engine for propulsion and an auxiliary engine for the ship's secondary systems. The engine feeds power through a transmission to the propeller to create the movement of the ship. Propulsion is what allows these large ships to move from place to place, but it can cause wakes that if close enough to land could decay the banks of that land. A typical cruise ship operates on a diesel engine and thus the source of energy for the engine is (diesel) fuel. The process of burning this fuel releases hazardous particulates into the air[17]. There are many factors that contribute to producing these emissions. The power of the engines, age, specific fuel oil consumption, running hours, load, and fuel consumption by the steam boiler, carbon content of the fuel, and the ship's speed all contribute to the levels of emissions that are produced[18]. These engines also produce a lot of noise and vibrations that could be propagated and cause structural damage to surrounding land masses, and the buildings [17].

Many small towns or cities on the water have a large number of cruise ships dock in their harbor each year. The small town of Skagway, Alaska, for example, has a population of just under 900 people. The Skagway harbor is shown in (Figure 8)[19]. On some days cruise ships can drop off more than 10,000 passengers at a time. That is 11 times the size of the actual population. Residents of Skagway cannot wait for the cruise ship off season so they

[15] Cruise Market Watch. "Cruise Market Watch Announces 2010 Cruise Line Market Share and Revenue Projections." http://www.cruisemarketwatch.com/blog1/articles/cruise-market-watch-announces-2010-cruise-line-market-share-and-revenue-projections (accessed 11/21/10).
[16] *2009 CLIA cruise market overview.* 2010 (accessed 9/18/2010).
[17] Bowman, Frank. "An Integrated Electric Power System: The Next Step." (April 8, 2008) http://www.navy.mil/navydata/cno/n87/usw/issue_9/power_system.html
[18] Buhaug, Ø, Corbett, J.J., Endresen, Ø, Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Markowska, A.Z., Mjelde, A., Nelissen, D., Nilsen, J., P ˚ alsson, C., Winebrake, J.J., Wu, W.-Q., Yoshida, K., 2009. Second IMO GHG study 2009. International Marittima Organization (IMO), London (UK).
[19] http://www.alaska-in-pictures.com/skagway-alaska-1011-pictures.htm

can recover the peace and quiet of their small town. As the passengers depart they can leave the town a little disheveled from the thousands of people squeezing into this small town[20].

Figure 8: Cruise ships Arriving at Skagway, Alaska Harbor

2.2 The Port of Venice

For cruise ships entering Venice there are three different spots that a cruise ship can dock: the Marittima, San Basilio, and Riva dei Sette Martiri Port Facilities (Figure 9).

Port Facility of "Marittima"   Port Facility of "San Basilio"   Port Facility of "Riva Sette Martiri"

Figure 9: Port Facilities of Venice

San Basilio has room for two ships. It is primarily used for impounded ships or for ships in transit. The Riva dei Sette Martiri is not an ideal location for a stop because there is no way of getting supplies to the ship in this location. It is used when there is an overflow in the harbor or if the ship wants a nice view of Venice. The Sette Martiri was the main location for docking before the Marittima existed. As passenger ships began to increase in size the residents of Venice began to complain about the ships ruining their view. They also complained about the pollution and most of all the noise that the ships created. The passengers also did not enjoy the location that the ships were docking because it was not in a tourist-friendly part of Venice[21]. This is when the main docking area of Venice became the Marittima.

[20] Klein, R. A. 2002. *Cruise ship blues: The underside of the cruise ship industry*New Society Pub.
[21] "Venice Terminal Passeggeri " http://www.vtp.it/calendario/ricerca.jsp?CercaNave=OK&password=null&CodNave=&CodArmatore=&Giorno=&Mese=&Anno (accessed 9/16/2010, 2010).

Figure 10: Marittima Location

The Marittima is a good location for turnaround ships especially because the ships can easily be replenished with supplies (Figure 10). There are six slots in the Marittima but terminal 123 always houses ferries[21] (Figure 12).

Figure 12: Docking Areas of Marittima

Venice is considered the leading homeport of the Mediterranean, and comes in second behind Barcelona in Europe[21]. Venice is an excellent homeport because of all the options passengers have to return home. The Marco Polo airport is just over the Ponte della Libertà in Mestre. There is also a train station within walking distance from the port just beyond Piazzale Roma. In addition, there are various ways to get off the island: buses, land taxis, and several kinds of boats. This ensures that if one method fails there is always another option (Figure 11).

Figure 11: Venice as a Good Homeport: Locations of Airport and Train Station

2.3 Cruise Ships in Venice

Venice's port has seen its passengers quadruple over the past 10 years, causing Venice to become the 4th most popular port in Europe. The Venice Terminal Passeggeri has put a limit on the size of ships entering Venice. The maximum length that the ship can be is 340 meters. Therefore the capacity of the ships visiting Venice has not increased quite as dramatically as in other leading ports around the world[22](Figure 13).

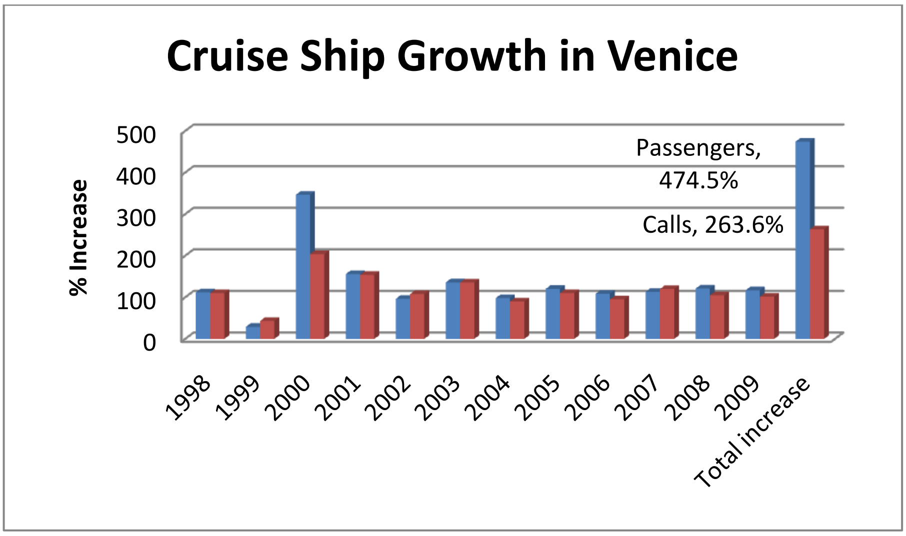

Figure 13: Cruise ship size increase in Venice

2.3.1Cruise Ship Operations

Each cruise ship making call in Venice is scheduled several years in advance. Before docking in Venice, it must confirm at least 24 hours ahead of time that it is still coming to give a good window of time that they will be arriving. If there is a delay after those 24 hours the ship informs and agent of whom will then inform the city that the ship will be arriving late. The ship must finally confirm both one hour before arrival and then again 30 minutes before arrival.

Approximately two miles from break water (the Lido Inlet in this case) a trained pilot boards the ship - two if the vessel is large enough. The pilot's main role is to act as an advisor to the captain, who never relinquishes command. With the pilot's expertise, the captain and crew work alongside one another to navigate through the narrow Giudecca Canal.[23] The Giudecca Canal is only 11 meters deep and an average cruise ship hull reaches nearly 10 meters below the surface. This could create an encounter with what Venetians call "Heavy Water," better known as sand[24]. After navigating through the narrow and winding Giudecca Canal, the captain takes complete control to dock the ship[23] (Figure 14).

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[22] "Venice Terminal Passeggeri " http://www.vtp.it/calendario/ricerca.jsp?CercaNave=OK&password=null&CodNave=&CodArmatore=&Giorno=&Mese=&Anno (accessed 9/16/2010, 2010).

[23] Nogara, Marco. Personal Interview. 19/11/2010. 19 Nov 2010.

[24] Campanol, Antonio. Personal Interview. 02/11/2010. 02 Nov 2010.

The pilot has control of the tugboats which are attached anywhere between when the pilot boards and San Andrea. Depending on the size of the ship one or two tugboats may be used, but in Venice at least one tugboat is required for each ship. The tugboats are used to escort the ship slowly through the Giudecca to the dock. Large ships typically have enough propulsion to turn themselves to get into the harbor but for some smaller ships or if the waters are rough the tug boats assist in the turning. The duration of the pilot and tugboat process is approximately two hours[25] (Figure 14).

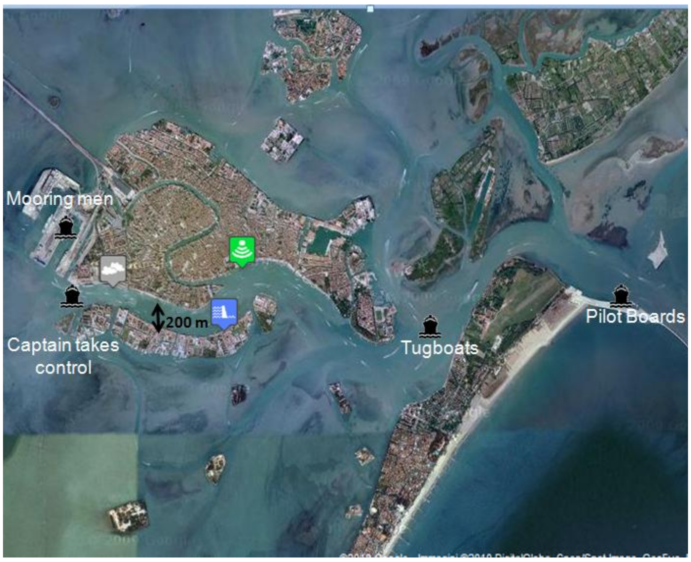

Figure 14: Cruise Ship Entrance to Venice

As these ships pass by Venice they have many different effects. The noise created by their engines creates vibrations that can damage the structures of Venice. As the ship passes by one of Venice's many canals it sucks the water out of the canal and briefly lowering the water level. The combustion of the fuel in their engines also creates dangerous air particulates (Figure 14).

Throughout this process the passengers inside are being ushered out of their rooms into a common area. They leave there bags outside the door where they will be picked up by housekeeping and unloaded off the ship. At this time cleaning of the rooms can commence[25].

In the Marittima the ship first turns off its generators that were used during the navigation into the harbor to reduce the amount of fuel used and pollution. Then the ship is unloaded, first the baggage and then the passengers. The baggage is unloaded using conveyer belts or walking planks and then is loaded onto carts to make its way to different areas of the harbor. After the baggage is off the ship the passengers begin disembarking. The passengers are given some sort of card, a color for example, that signifies when they will be disembarking. A card is called overhead telling the passengers with that card that they are able to disembark at that time[25]. After disembarking the passengers must go through customs and then find their way out of the harbor using one of the

Figure 15: Transportation Options

25 Nogara, Marco. Personal Interview. 19/11/2010. 19 Nov 2010.

five modes of transportation: walking, the people mover, taxis, boats, and buses. This influx of passengers could have a significant impact on mobility within the city (Figure 15).

As Venice's status as a leading homeport would imply, many of the ships' passengers do not visit the city after they have disembarked. They often go directly to the airport, train station, or bus station. Tourist visits to Venice are generally made before passengers embark on their ship[26].

After the passengers have completely disembarked, the ship will begin its basic turn around maintenance. This involves removing all the garbage from the ship, cleaning the ship inside and out, and replenishing supplies. Bilge and septic waste are removed via pump barge. The entire ship is essentially turned over and cleaned on the inside. Its hull is often washed and sometimes repainted, since many are white become dirty quickly. Supplies such as food, cleaning utensils, and laundry are replenished by trucks that are filled with pallets. Finally, fuel is replenished with several barges[27].

The ship undergoes basic mechanical maintenance during its stay in the harbor as well. A check of the ship is always done, but occasionally there are more serious problems where a contractor would come into the harbor to repair the ship. The ship may also go through standard inspections while it is in dock[27].

[26] Campanol, Antonio. Personal Interview. 02/11/2010. 02 Nov 2010.
[27] Zanforlin, Marco. Personal Interview. 11/11/2010. 11 Nov 2010.

3. Project Boundaries and Organization

The mission of this project is to further the understanding of the impacts of cruise ships on the city of Venice. It can be broken down into four main objectives: to quantify the vibrations felt across the city, analyze the hydrodynamic effects on Venice's waterways, measure the particulate emissions produced around Venice's harbor, and to document the transportation choices for disembarking passengers.

This project took place from 25 October to 17 December. All data collection took place when the cruise ships were arriving and leaving Venice in accordance with the cruise ship schedule (Appendix B). This occurred mostly on the weekends and in the early morning.

This project focused only on cruise ships. These specific vessels are large passenger ships used commercially for pleasure vacations. The specific vibrations studied were measured from buildings and the foundation material. The effects passing cruise ships have on the hydrodynamics of the canals were also studied to include the change in velocity of the water flow and the change in height of the water in the canals. The particulate studied was black carbon emitted from the burning of diesel fuel. Five transportation modes for disembarking passengers were also studied: walking, the people mover, land taxis, boats, and buses. The people mover is a new automated tram shuttling pedestrians between Piazzale Roma and Tronchetto from the harbor.

Most studies took place within the Venice Harbor facilities and around the people mover for transportation and particulate emissions measurements. The vibration and hydrodynamic measurements took place along both flanks of the Giudecca Canal.

Figure 16: Area of Study

Figure 16 illustrates the "Area of Study" for all four objectives. The studies investigated the current operations of cruise ships in the Lagoon; all ships enter through the Lido Inlet (included on the right) and transit to the Venice Harbor via the St. Mark's Basin and Giudecca Canal.

The remainder of this report is organized by each objective. Each major section contains a brief background, methodology, results and conclusions, and recommendations for each effort. This was done to ensure that each objective was fully understood and followed through.

4. Quantifying the Vibrations

One of the main complaints of the residence of Venice when the ships docked in the Riva dei Sette Martiri was the noise and vibrations that were created by the engines. The vibrations produced by the cruise ships are primarily impulsive; this means that they are short transient vibrations. Over an extended period of time these vibrations can cause structural damage[28]. Traffic can generate waves similar to that of the ones created by ships. When these traffic waves have a short period, small amplitudes, large frequencies and fast accelerations is when they become a danger[29].

The effects of these types of vibrations on structures have been found to be destructive. Over time vibration can create deterioration of material properties[30], such as stiffness and mass or energy displacement[31]. These vibrations can initiate or speed up the process of liquefaction. This is when stone and soil experience an increase in pore-water pressure causing them to transition from a solid state in to a liquefied state. The increase in pore-water pressure is initiated by prolonged shaking; typically in a cyclic pathway[32]. Figure 17 depicts the results of liquefaction in sediment. The damage the vibration causes to the stone depends on the strength of the stone itself. Judging on how old many of the structures in Venice are it is likely that the stone is old and not stable[30].

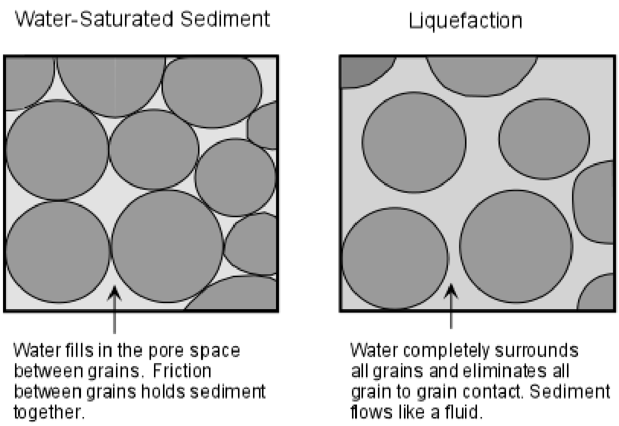

Figure 17: Liquefaction

[28] F. Schiappa de Azevedo, J. Patricio. "ANNOYANCE AND DAMAGE IN BUILDINGS CAUSED BY VIBRATIONS. CONSIDERATIONS FOR A VIBRATION CONTROL GOOD PRACTICE." *Acustica* 2010, no. 9/18/2010 (2004) (accessed 9/18/2010).
[29] Bata, Miloslav. "Effects on Buildings of Vibrations Caused by Traffic." *Building Science* 6, no. 4 (12, 1971): 221-246.
[30] Dimentberg, Mikhail. , Edited by Cortney Davis, 2010.
[31] Farrar, C. R., S. W. Doebling, and D. A. Nix. "Vibration-Based Structural Damage Identification " *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 359, no. 1778 (2001): 131 <last_page> 149.
[32] Carminati, Eugenio, Silvia Enzi, and Dario Camuffo. "A Study on the Effects of Seismicity on Subsidence in Foreland Basins: An Application to the Venice Area." *Global & Planetary Change* 55, no. 4 (02, 2007): 237-250, http://search.ebscohost.com/login.aspx?direct=true&db=8gh&AN=23741268&site=ehost-live.

It is possible that the cruise ships are not the only contributing factor to the deterioration due to vibration in Venice. Venice sits 50km away from the closest active fault and is located on the footwall of the thrust faults that surround Po Plain[33]. Another event that could cause vibrations is pedestrian movement[30]. These vibrations are created simply from people walking, particularity if people are walking in sync with each other and applying a lot of force to each step[30]. These vibrations can explain how some of the vibrations may also be created by the earth and not by the cruise ships.

Vibrations can be measured by accelerometers. An accelerometer contains a crystal that is stressed by even a small acceleration. The crystal will then produce a voltage that can be read and recorded as a number. This accurately records the acceleration that the accelerometer is experiencing[34]. This acceleration can be converted into a rotation measurement if needed. Many modern cell phones, especially smart phones, use the accelerometer technology to produce games or make phone usage easier. For example if the phone is turned from a horizontal to vertical position the image on the screen changes with it.

4.1 Methodology

We studied the vibrations created on the island by using the Sensor Insider Pro application (Figure 18) that uses the accelerometer in an android phone. The accelerometer is extremely sensitive and is able to detect even the slightest movement.

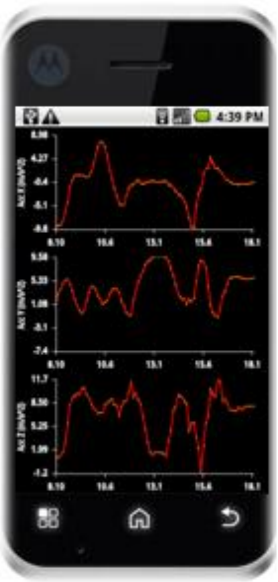

Figure 18: Sensor Insider Pro Application

There is no available data to start from on the vibration effects of cruise ships in the city of Venice. Therefore all of the data was collected by the team in the duration of the stay

[33] Carminati, Eugenio, Silvia Enzi, and Dario Camuffo. "A Study on the Effects of Seismicity on Subsidence in Foreland Basins: An Application to the Venice Area." *Global & Planetary Change* 55, no. 4 (02, 2007): 237-250, http://search.ebscohost.com/login.aspx?direct=true&db=8gh&AN=23741268&site=ehost-live.

[34] "Dimension Engineering." *A Beginner's Guide to Accelerometers.* N.p.n.d. Web. 11 Dec 2010. http://www.dimensionengineering.com/accelerometers.htm.

in Venice. The main goal of this portion of the project was to determine if there are measureable vibrations caused by cruise ships on the city of Venice, and if so to determine their effects.

All the data measurements were taken between October 30, 2010 and November 21, 2010. The measurements were taken when the cruise ships were coming into port so they were taken according to the cruise ship schedule for each day (Appendix B - Schedule (Cruise ships and Data Collection)). To ensure that the graph could be read properly a corresponding video of the passing of the ship was taken for each measurement. This video was lined up with the corresponding portions of the graph by carefully recording the times on the camera as well as the application. The times that were recorded were when the accelerometer was turned on, when the cruise ship was visible, when the ship was directly in front of the phone, when the ship was no longer visible. Some passing boats were also recorded to obtain a finer degree of accuracy.

The accelerometer was placed in many different locations along the Giudecca Canal to determine if the passing cruise ships created any vibrations more than the normal boat traffic (Figure 19). Factors that were considered were the age and the size of the ship. To do this the age and the size of each ship was determined (Appendix D - Size and Age of Cruise Ships).

Figure 19: Vibration Measurement Locations

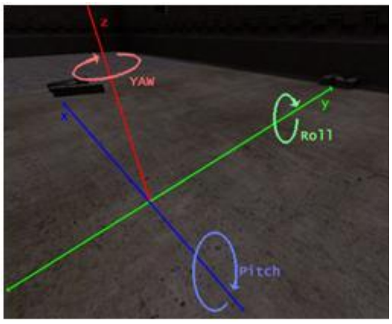

Figure 20: Angular Measurements

The application used was the Sensor Insider Pro. This application measures the acceleration which then can be converted into orientation measurements: pitch, roll and yaw (Figure 20[35]). These are different measurements of angular rotations that the phone is experiencing as the phone is moved. Once the application is downloaded and open on the phone the data collection can begin by simply pressing the menu button and then the start button. To end

ıke3_mapping_yaw_pitch_roll_tut.htm

the data collection simply hit the menu button again and then hit the stop button. This data will then need to be exported to an excel file, and to do this under the menu button there is an export option with a file compatible with excel. The phone will then need to be connected to the computer with an USB cable and downloaded onto the computer. Once the data is in an excel file graphs are created to visualize the results.

For each measurement of a passing ship the x-acceleration graph is shown and the y and z graphs of acceleration are shown in Appendix E - Y and Z Acceleration Graphs. For the graphs of the *Costa Fortuna* and the *Queen Elizabeth* the minimums and maximums were recorded. These times were used to find out what precisely occurred at each of those peaks by viewing a corresponding video. This is shown in Appendix F - Vibration Graph Minimums and Maximums.

4.2 Results and Conclusions

The *Queen Victoria* is classified as a large new ship. The measurement was taken at Riva dei Sette Martiri. Figure 21 shows the results when the phone was placed near a ship that was docking:

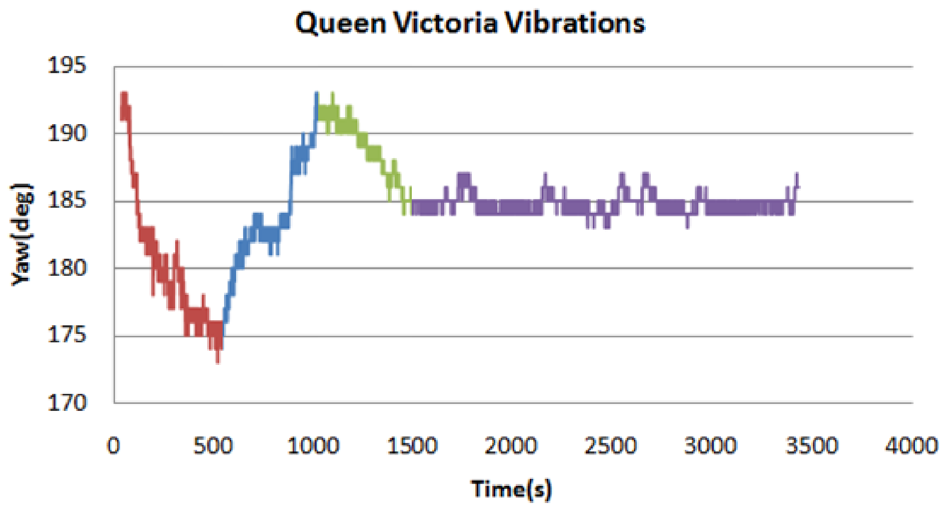

Figure 21: Docking Ship Vibrations (10-30-2010)

The acceleration graphs did not show much so the orientation graph that showed the most was used. Based on the orientation, the phone was only significantly rotating in the yaw direction, around the z-axis. The phone was placed as engines shut off (Red) and as it starts to approach the dock the phone starts to rotate the other way (Blue). The upwards spike is as the planks were being placed down (Green). The area following that is as the passengers were disembarking (Purple).

The *Costa Fortuna* is classified as both a large and new ship. These measurements were taken at San Basilio (Figure 22):

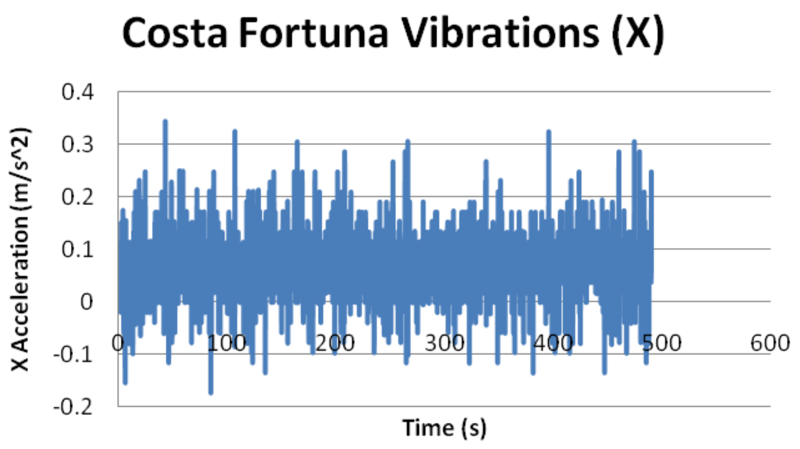

Figure 22: *Costa Fortuna* x-Acceleration at San Basilio (11-15-2010)

The ship passed at 187 seconds and was through passing at 408 seconds. The largest maximum, at 34 seconds, was when an alilaguna passed close to the shore, and the largest minimum, at 85 seconds, when a personal boat passed. Both of these peaks were before the cruise ship passed. There is not a significant change anywhere between these two times.

The *Queen Elizabeth* is also classified as a large and new ship. These measurements were taken at San Basilio directly following the *Costa Fortuna* (Figure 23).

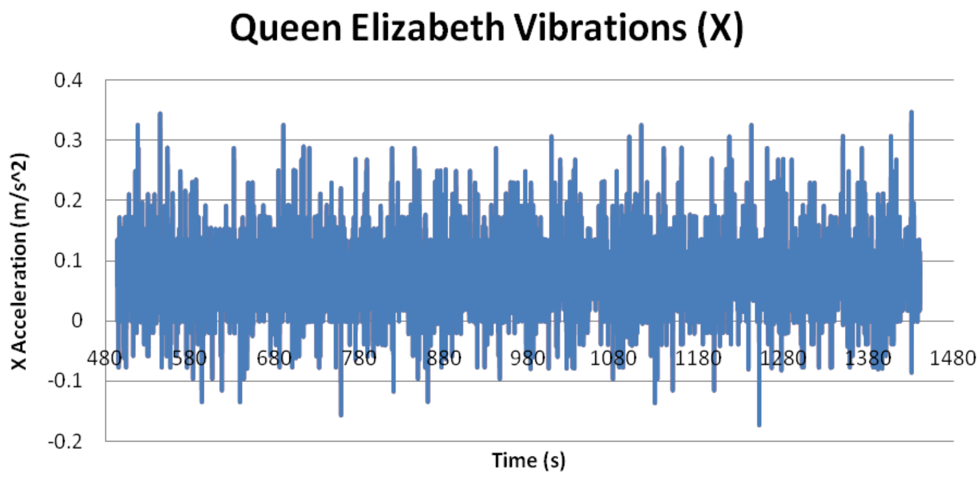

Figure 23: *Queen Elizabeth* x-Acceleration at San Basilio (11-15-2010)

The cruise ship comes into frame at 647 seconds on phone and the tugboat leaves the frame at 1129 seconds on the phone. The largest maximum, 544 seconds, was when a coast guard boat passed, and the minimum, 1251 seconds, was a water bus passed. There is not a significant change anywhere between before the ship passed, while the ship was passing and after the ship passed.

The *Costa Serena* is classified as a large but old ship. These measurements were taken at San Basilio (Figure 24):

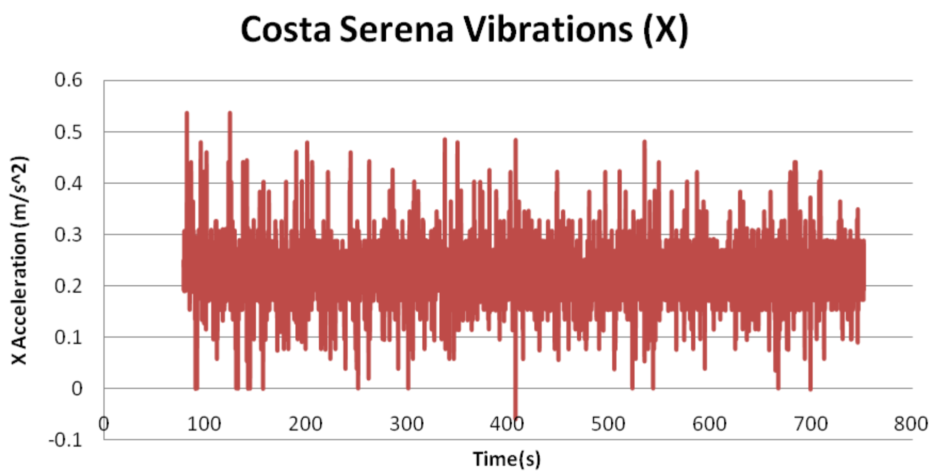

Figure 24: *Costa Serena* x-Acceleration at San Basilio (11-21-2010)

The ship passed at 487 seconds and was through passing at 673 seconds. There is not a significant change anywhere between these two times. This ship had an older engine so it was expected to create more vibrations than that of the newer ships. Since no vibrations were detected the phone is not sensitive enough to detect the vibrations from passing distance.

The *MSC Magnifica* is classified as a large and new ship. These measurements were taken along the Zattere walkway (Figure 25):

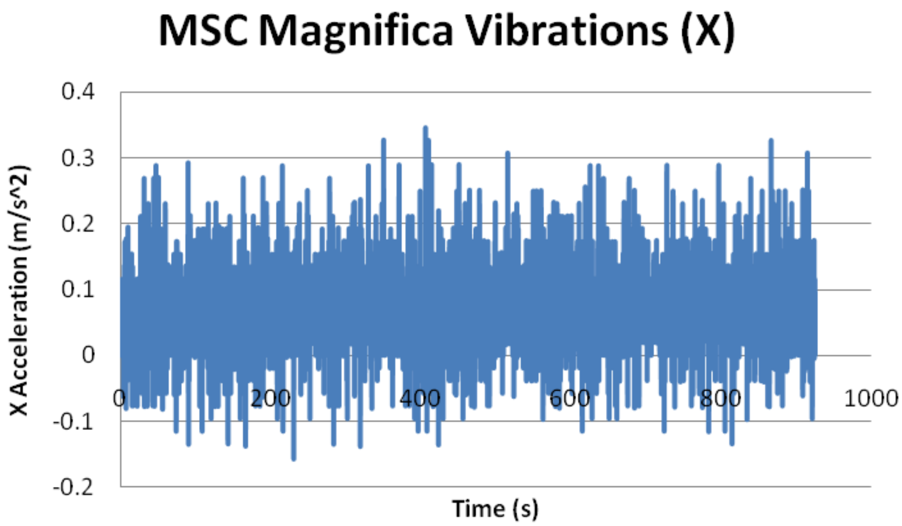

Figure 25: *MSC Magnifica* x-Acceleration at Zattere (11-20-2010)

The ship comes into frame at 125 seconds on phone and the tugboat leaves the frame at 325 seconds on the phone. There is not a measureable change from before the ship passed and as the ship was passing. This ship is similar in size and age to the *Costa Fortuna* and the

Queen Elizabeth. The graphs for these three ships should have been very similar. The graphs were similar but only because they did not detect any vibrations.

The peaks that are visible on the graphs of acceleration are of passing boats or ferries. These peaks were not sustained for a long period of time and they were not always observed in the same part of the frame in the video. This could have happened because the phone detected a loud or especially strong type of noise or vibration from the engine. Since the engines would not always have a strong vibration at the same time on the frame in the video.

Many of the minimums and maximums correlate with a time when there was a smaller boat passing, such as an alilaguna or a garbage boat. There are also a minimum or maximum when the tugboats pass. They are all only peaks though none of the vibrations are sustained. This leads to the conclusion that there are vibrations created by the cruise ship but the device was not sensitive enough.

4.3 Future Recommendations

While cruise ships create vibration the device that was used was not sensitive enough. For the coming year the students should try to obtain a better device to measure the passing ships. A seismograph is one possible option. These are much more sensitive but may be expensive. If a more sensitive device can be obtained many more measurements should be done to analyze the effects of the vibrations created by the passing cruise ship. The measurements should be taken right along the Giudecca Canal. This is the closest to a cruise ship that the device can be so it is an ideal spot for testing the sensitivity of the device. If vibrations are able to be detected along the Giudecca Canal then other measurements can be made further into the city to determine if the vibrations are affecting the inner city of Venice.

5. Analyzing the Hydrodynamic Effects

Hydrodynamics is the study of fluids in motion. When considering the local aspects of Venice's canals, one must first understand the dynamics of the entire Venice Lagoon. In fear of losing the lagoon due to progressive siltation from river beds during the 16th Century, Venetians dug canals which diverted the main rivers away from the Lagoon and into the Adriatic Sea. The Lagoon has been experiencing constant erosion ever since, up to about 1.1 million cubic meters of sediment a year[36]. These 16th century measures reversed the Lagoon's tendency to silt up, thus creating a more sea-like environment. These facts offer great fortune for cruise liners, but are not so fortunate for a city made up of dozens of small islands.

Although encompassing an intricate network of canals, the overlying hydrodynamic effect relies on the tidal flow; the trends are predictable. During the flood tides, the flow is predominantly from southeast (Adriatic Sea) to the northwest. The average current velocity in the canals is rather slow, about 0.25 m/s (0.56 mph)[37]. Past studies in the Venice Project

[36] Apitz, Sabine E., Andrea Barbanti, Martina Bocci, Anna Carlin, Laura Montobbio, and Alberto Giulio Bernstein. 2007. The sediments of the venice lagoon (italy) evaluated in a screening risk assessment approach: Part II--lagoon sediment quality compared to hot spots, regional, and international case studies. *Integrated Environmental Assessment & Management* 3 (3) (07): 415-38

[37] Coraci, Elisa, Georg Umgiesser, and Roberto Zonta. "Hydrodynamic and Sediment Transport Modelling in the Canals of Venice (Italy)." *Estuarine, Coastal and Shelf Science* 75, no. 1-2 (10, 2007): 250-260.

Center have given rise to new questions: How much can passing cruise liners actually affect this flow? Are these hydrodynamic fluxes damaging to the canal walls and basins? According to Archimedes' Principle, the mass of a statically floating material is equal to the mass of water it displaces[38]. Therefore if the weight of the ship is known the volume of water that is displaced by certain ships can be calculated. With this data, the forces of water friction along the canal walls can be approximated, and there will be a much better idea of the damage caused by ships, if any at all.

Further understanding of the nature of dynamic fluids is essential for studying the effects specific to cruise ships around Venice proper. Two critical principles will be covered: the continuity equation from conservation of mass, and Bernoulli's principle. The continuity equation, although a product of a fluid's cohesive and surface tension properties, helps explain why fluids always take the shape of their container. The principle governed by the equation states that a fluid's velocity gradient will always equal zero:

$$\nabla V = \left(\frac{\partial V}{\partial x}\right) + \left(\frac{\partial V}{\partial y}\right) + \left(\frac{\partial V}{\partial z}\right) = 0$$

Through inspection, it is clear that if forces are applied to a body of water, and motion ensues in one direction, reactive motion in the other two directions becomes necessary for the velocity gradient to equal zero. For instance, if a cruise ship were to cause motion of water in one canal at a high enough magnitude, an acceleration of flow in adjacent canals would be expected.

When considering Archimedes' Principle of water displacement, it is rather counter-intuitive that water would accelerate in the direction of a cruise ship's approach, instead of away from its massive presence. It is important to distinguish that water is not "sucked" under large moving ships, ending up behind the ship in its wake. Rather, the fluid dynamics around a transiting ship's hull behave nearly identically to an airplane's wing. According to Bernoulli's Principle, "a fluid's pressure decreases as its velocity increases." Bernoulli's equation is therefore:

$$P + \frac{\rho V^2}{2} + \rho g z = constant$$

Where P is the instantaneous pressure, ρ is the fluid's density, V is the instantaneous velocity, g is the gravitational constant, and z is the relative elevation. Bernoulli's equation leads to the conclusion that as water accelerates around a ship's hull (Figure 26), there must be an area of low pressure around of the ship in motion. Paired with the continuity equation (mass conservation), it is clear that as a moving ship approaches nearby canals, water must *replace* the displaced fluids in front of a moving ship, and quickly.

[38]Ship Hydrodynamics, Encyclopedia Britannica <http://www.britannica.com/EBchecked/topic/540904/ship/64197/Ship-hydrodynamics>

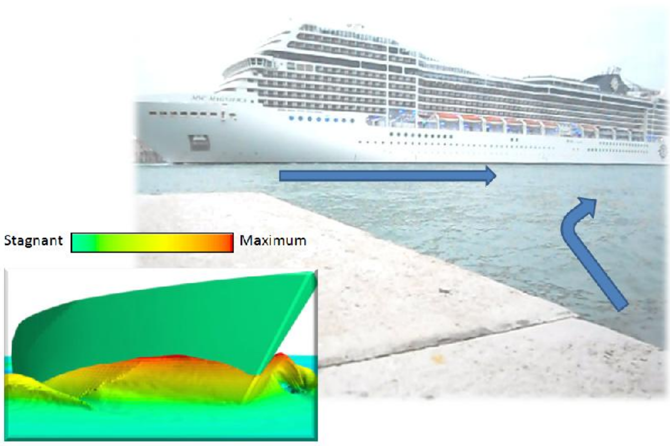

Figure 26: Water Accelerates Around Ship's Hull

After meeting with representatives from the National Research Council – Institute of Marine Sciences (CNR-ISMAR) in Venice, it was concluded that these explanations for water acceleration in adjacent canals were accurate. Their research concluded in June, 2004 studied the flow velocity, water height, and turbidity of several canals adjacent to the Giudecca Canal and St. Mark's Basin during the passage of a multitude of passenger ships. Their results concluded that the canals' flow velocity increased while the water height lowered. The velocity and height graphs taken during the passing of the European Vision were super-imposed in Figure 27. The turbidity graph (not shown) showed little increase during the same time period, but to a lesser degree than the increases in velocity and lowering of the water's surface. This would suggest that the passenger ships increase the current, but that the flow is rather docile and is actually less turbulent than the natural tidal flow.

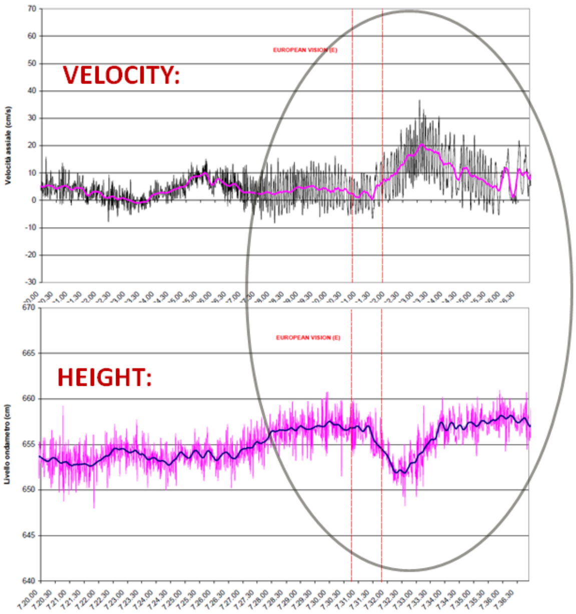

Figure 27: Canal Velocity (Top) and Height (Bottom) Graphs
for the European Vision

After studying the effects of several passenger ships of different sizes, the CNR-ISMAR study came to another conclusion – the determining factors of the different levels of effect. First is the size (mass), including the geometric characteristics of the vessel, explained by both Archimedes' and Bernoulli's Principles, respectively. Second is the vessel's speed; third is the ship's distance from the shore or canal's opening. The final factor, and certainly the most important for visualizing the effects, is the tidal condition such as water level and phase. The effects were most noticeable during low tide conditions, simply because there is less water in a given area.

5.1 Methodology

During the research phase of this project, Worcester Polytechnic Institute's Professor David Olinger, a leading fluids expert in the field of Aerospace Engineering was consulted. The expectations of the fluid mechanics within canals, and possible causes for the increase in canal velocity moving towards a transiting ship were discussed. This preliminary research indicated that as water accelerates within an enclosed path, such as a Venetian canal, shear stresses are induced on the canal walls. These stresses are completely dependent upon the canal's geometry, but most importantly, its velocity. Properly measuring the canal velocity is therefore paramount.

Figure 28: Hydrodynamic Measurement Locations

The City of Venice published a report in June 2004 stating that the transiting cruise ships' effects on the canals were negligible. Their methodology and budget were much more sophisticated than anything available to the Venice Project Center. The water speed was calculated with volumetric flow; a device submerged in the water collecting data of water flux in real time. In addition, the water height was recorded with remarkable precision - about 50 data points per second using acoustic and Doppler radar instruments.

The goal of this portion of the project was to qualitatively validate the data collected by the city of Venice in 2003, and to determine whether or not the stress levels are truly negligible. The primary focus was to offer visual support for their conclusions using both time lapse and real-time footage, capturing both the increase in speed and change in canal height. The particular canals studied are shown in Figure 28.

Further research indicated that a simple device has been used by UNESCO and another Venice Project Center team (Return to the City of Water: Quantifying Change in the Venetian Canals) to measure canal flow rates. As illustrated in Figure 29, the device is rudimentary but highly effective for natural flow measurement. The large cross-sectional sheet metal array can be made from soft drink cans. The underwater portion is weighed down by a fishing lure; it's neither too heavy to sink nor light enough to experience heavy wind effects. The twenty-ounce soft drink bottle and fishing line allows the user to track and recover the device throughout measurement.

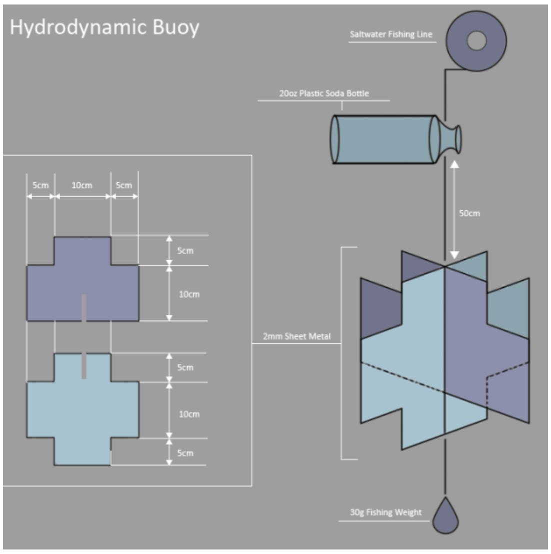

Figure 29: Device Schematic for Measuring Canal Velocity

Using this device, the average flow velocity was measured through a simple equation: speed equals distance traveled over time. A stopwatch was used to calculate the time travelled over each interval. Measurements were taken every 3 meters along a 24 meter distance as shown in Figure 30 below.

Test 1											
Ship:	Star Princess			AVERAGE VELOCITY 30 MIN BEFORE PASSING:			0.52 m/s				
									% Increase:	65.2	
Tidal Condition:	3.5 hours after high tide			MAXIMUM VELOCITY:			0.78 m/s				
Wind:	Approx 10 mi/hr from South			MINIMUM VELOCITY:			0.51 m/s				
	FLOAT 1				FLOAT 2				FLOAT 3		
	Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)
	3	5.8	0.517241379		3	4.1	0.731707317		3	4.95	0.606060606
	6	5.6	0.535714286		6	4	0.75		6	5.1	0.588235294
	9	5.7	0.526315789		9	3.85	0.779220779		9	5.3	0.566037736
	12	5.5	0.545454545		12	3.95	0.759493671		12	5.55	0.540540541
	15	5.35	0.560747664		15	4.2	0.714285714		15	5.6	0.535714286
	18	5.05	0.594059406		18	4.3	0.697674419		18	5.8	0.517241379
	21	4.75	0.631578947		21	4.5	0.666666667		21	5.75	0.52173913
	24	4.4	0.681818182		24	4.8	0.625		24	5.9	0.508474576

Figure 30: Velocity Test Results Form for *Star Princess* (see also Table 11)

Distinguishing the increase in flow due to transiting cruise ships was the most important aspect of the measurements. Flow rate data was measured about thirty minutes before the cruise ship passed, to offer a baseline for the natural flow. During the actual passing, the devices covered much more distance than the 24 meter testing area, so two identical buoys were used in order to "piggy-back" the measurements. In the time it took to determine the maximum and minimum canal speeds, three linear measurements were taken. Essentially, multiple devices ensured that there was at least one float in the water throughout the ships' passing. In addition, it was useful to have several "control distances" to see both the flow's change in velocity as well as its flow with respect to the ship's position.

Contrary to initial research, the flows never changed direction during any portion of the ships' passing. Figure 28 illustrates the four canals in which measurements were completed; all have similar dimensions and natural flow – all towards the Giudecca Canal. These canals were flanked with sidewalks (fondamente) to measure the distance between checkpoints and track the flotation device.

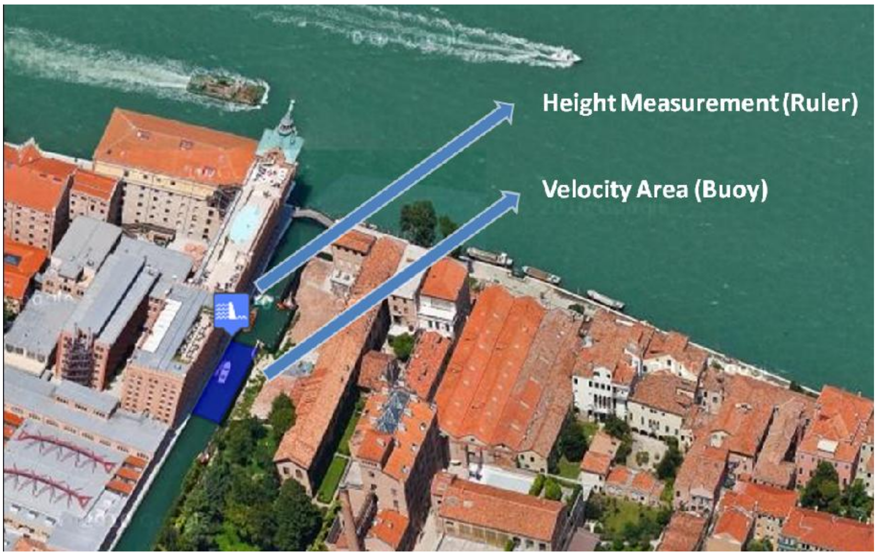

Figure 31: Measurement Locations along Rio di San Biagio

The primary location in which hydrodynamic measurements were taken was along the fondamenta flanking the San Biagio Canal in Giudecca. Velocity and water height measurements were taken in the same location – at least 50 meters away from the threshold with the Giudecca Canal. Interior canals tended to experience fewer wakes and less wave interference. Shown in Figure 31, the hydrodynamics icon points out the ruler's location along the fondamenta and the blue area denotes the specific 24 m area in which velocity measurements were taken. The ruler was secured to a wooden dock, while a real-time camera was used to manually record the water levels (3-4 frames per second) at a later time.

5.2 Results and Conclusions

Given the more sophisticated methodology and extensive budget of Venice's Institute of Marine Research (ISMAR), the primary hydrodynamic objective was to validate ISMAR's research: both quantitatively and visually. Five canal velocity tests and two height measurements were taken. During two principle tests – the passage of the *MSC Magnifica* and *Costa Serena* – the four determining factors were held as close to constant as possible. The ships were of comparable size, both transited at no more than 5 km/hr, and the tests were taken 2 hours after high tide. The maximum canal velocities were quite remarkable, increasing 57.4% of the initial velocity. At its lowest sustained point, the water level was also lowered 11cm.

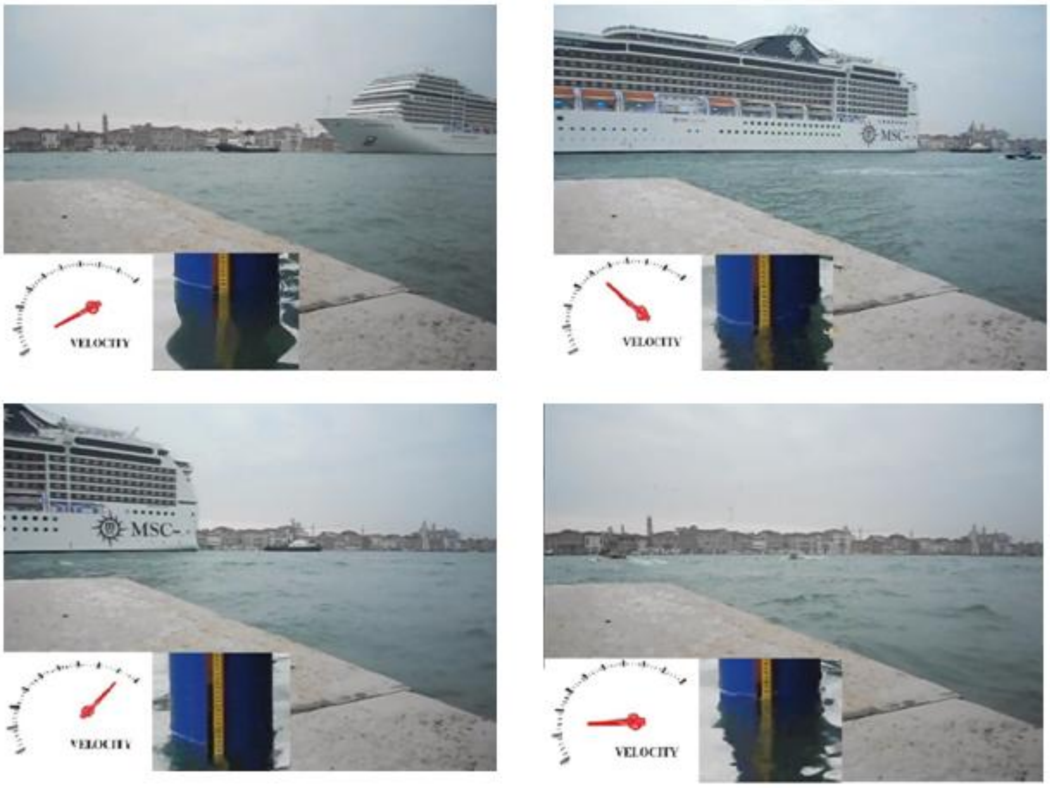

Figure 32: Velocity and Height Measurements during Passing of *MSC Magnifica*

The research accomplished two objectives; first determining precisely why these hydrodynamic effects take shape. Bernoulli's Principle of lowering pressure and Archimedes' Principle of water displacement were the overlying explanations. The water traveling around the ships' hull accelerated with such magnitude that it pulled a noticeable amount of water from canals adjacent to St. Mark's Basin and the Giudecca Canal. As visualized in Figure 32, the velocity gauges indicate the proportion of canal speed with respect to the canal height during the passing of a cruise ship. Conceptually, the increase in flow lowered the water level, and both speeds and heights were gradually restored to their original values after passage. The measurements did not indicate that the canals' flow changed direction.

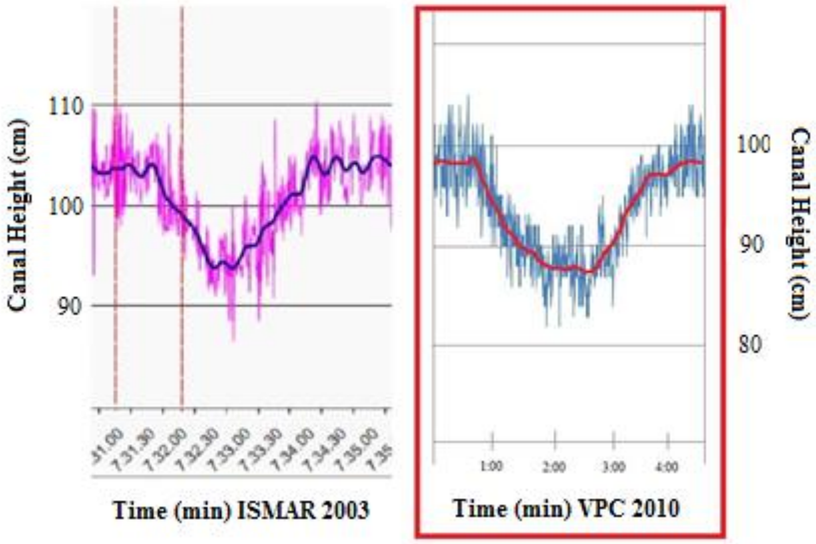

Figure 33: Side by Side Graphs for *European Vision* (left) and *MSC Magnifica* (right)

Second, the results suggest that ISMAR's conclusions were well-founded. Figure 33 outlines both the canal height measurements from the *European Vision*'s passing in 2003 (left) and the measurements from the *MSC Magnifica*'s passing (right, outlined in red). These side-by-side graphs show a sustained drop of 10-12 cm for nearly 2 minutes. With the visual support in Figure 32 and quantitative validation in Figure 33, the conclusion can be made that transiting cruise ships cause significant alterations to the natural canal flows. The extent to which these alterations cause permanent damage to canal walls is minimal, but requires much more extensive research.

5.3 Future Recommendations

First and foremost, a more professional relationship with CNR-ISMAR needs to be established, primarily with Luca Zaggia. He has an incredible amount of knowledge pertaining to the hydrodynamics of the Venetian Lagoon and has complete access to all of Venice's marine vessel research projects. ISMAR's study of passenger ships traveling through the St. Mark's Basin and the Giudecca Canal was only one study of several; they have made impressive headway on studying the turbidity caused by many large vessels, the major depression waves, and other extensive research. His cooperation is a crucial first step to conduct further hydrodynamic studies of passenger ships in Venice.

As outlined in the background research, there are four factors that determine the extent to which cruise ships affect a canal's natural flow. Future projects should validate these factors. For instance, consider solidifying the relationship between a ship's size and weight to the induced effects such as flow velocity and turbulence. Although ISMAR's researchers concluded that their effects were not immediately damaging to the canal walls, the long-term effects cannot be overlooked. Mr. Zaggia has access to several pressure sensors, which could potentially be placed into the canals during a ship's passing to get a better idea of the stresses on the canal walls. Preservation of Venice's physical foundations is a powerful effort, and should not be taken lightly.

6. Measuring the Particulate Emissions

Air quality is an essential part of the environment. The emissions created by the burning of diesel fuel contain a number of air pollutants that can result in harmful health effects (Figure 34). "Particulate matter (PM), volatile organic compounds (VOCs), nitrogen oxides (NOx), ozone, and sulfur oxides (SOx)[39]" are only a few of the pollutants present at seaports all over the world.

Figure 34: Air Pollution

Not only do some of these pollutants rank as some of the top contributing factors to global warming[40], but they are also known to cause varying degrees of health problems. "The health effects of these air pollutants to residents of local communities include asthma, other respiratory diseases, cardiovascular disease, lung cancer, and premature mortality. In children, there are links with asthma, bronchitis, missed school days, and emergency room visits[41]." The local residents of the destinations visited by cruise ships may experience the most risk. Long-term exposure to aerosol black carbon can lead to physiological, chemical, physical and microphysical effects[42]. These effects can be noticeable in the environment. For example, heavily polluted cities experience brown skies and reduced visibility, commonly referred to as "smog." The chemical reactions associated with black carbon can leave residue on structures and artworks in Venice. These structures must be scrubbed clean in order to be preserved. It is not only costly to clean the buildings and artwork, but can potentially degrade the quality of the affected pieces.

[39] Bailey, D., and G. Solomon. "Pollution Prevention at Ports: Clearing the Air." *Environmental Impact Assessment Review* 24.7-8 (2004): 749-74. Web.; p. 751
[40] Velchev, K., F. Cavalli, J. Hjorth, E. Marmer, E. Vignati, F. Dentener, and F. Raes. "Ozone Over the Western Mediterranean Sea–results from Two Years of Shipborne Measurements." *Atmospheric Chemistry and Physics Discussions* 10; p. 6130
[41] Bailey, D., and G. Solomon. "Pollution Prevention at Ports: Clearing the Air." *Environmental Impact Assessment Review* 24.7-8 (2004): 749-74. Web.; p. 749
[42] Hansen, Tony, MaGee Scientific Corporation, accessed October 1, 2010, http://mageesci.com/support/downloads/micro/microAeth_AE51_Operations_Manual_Jun-09.pdf.

“In Europe, land based emissions of sulfur have been successfully reduced since 1980’s[43].” Since the land based emissions were reduced, this means that cruise ships play a major role in the emission of sulfur in that region of the world. There are laws and regulations in place to attempt to monitor the harmful pollutants that are caused by the cruise ships. However, there are still environmental impacts that need to be considered. The cruise liners are frequently moving from destination to destination and do not necessarily see the direct effects on the areas they visit, both on the environment and the local population. Cruise liners have been forced to comply with environmental sustainability regulations, both local and federal. However, there is always room for improvement with new technologies being released[44].

Figure 35: Air Pollution from a Cruise Ship (1)

Cruise tourism plays a large role in the economy of Venice, but at what point do the environmental effects outweigh the profits from the presence of the cruise ships? This is a question that has been raised numerous times in Venice. However, the city continues to allow the cruise ships safe passage into the historic city. Tourists may not be affected by, or notice, the environmental effects caused by the air pollution that these cruise ships produce. This means that it will be up to the local governments that will assess the impacts on the city. These impacts can range from infrastructure, operational, distribution, use, and waste. An example of an infrastructural impact would be that many of ship destinations must make structural modifications to the environment in order to accommodate the ships. Operational impacts involve the use of energy, water and air quality pollution. Distribution impacts encompass the transferring of people to and from departure and destination points. Use impacts are related to the consumption of natural resources, such as water, and recreational activities on wildlife, such as disturbance and littering. Oils, garbage, sewage, plastics, and hazardous substances are all different forms of waste that need to be handled and disposed of in a certain way[45]. Each one of these impacts involves the use of vehicles and equipment, which are most likely powered by carbonaceous fuel. This means that all of these impacts that were indirectly created by these cruise ships also produce air pollutants. Ultimately, the

[43] Marmer, E., F. Dentener, JV Aardenne, F. Cavalli, E. Vignati, K. Velchev, J. Hjorth, F. Boersma, G. Vinken, and N. Mihalopoulos. "What can we Learn about Ship Emission Inventories from Measurements of Air Pollutants Over the Mediterranean Sea?" *Atmospheric Chemistry and Physics Discussions* 9, no. 2 (2009): 7155-7211; p. 7157
[44] Klein, R. A. 2002. *Cruise ship blues: The underside of the cruise ship industry*New Society Pub.
[45] Johnson, D. "Environmentally Sustainable Cruise Tourism: A Reality Check." *Marine Policy* 26.4 (2002): 261-70. Web.

air pollutants produced by cruise ships directly and indirectly can lead to depopulation and unsustainable environments in the local communities if precautions are not taken.

6.1 Methodology

In order to accomplish the third objective, an instrument known as an "aethalometer" was used. This instrument measures the black carbon present in the atmosphere. The team was able to obtain two devices from the CEO of Magee Scientific, Jeff Blair. Black carbon was the pollutant chosen to study the emissions from cruise ships for several reasons. First, black carbon has direct and indirect effects, which include physical, chemical and physiological. As similarly stated above, this simply means BC has an impact on climate change, visibility, structural composition, and on public health and disease. Second, the particulate matter is a good tracer to indicate the movement of meteorological air masses. Lastly, according to Magee Scientific, BC is the second leading cause of global warming. Data was collected from 11/11/10 to 12/6/10 to properly measure the black carbon present in Venice and ultimately get an understanding of the emissions' effects on the city.

Aethalometer®

microAeth® Model AE51

Figure 36: microAeth Model AE51

MAGEE SCIENTIFIC

http://mageesci.com/

The aethalometer uses an optical filtration system to measure the "blackness" of the particulate matter (black carbon) that is collected onto a T60 Teflon-coated borosilicate glass fiber filter material. The optical analysis and data readout is performed "on the spot" and requires no further analysis in a laboratory.

After ensuring the instrument is fully charged, a new filter ticket must be installed, which can be seen in Figure 91. This is a very simple step but imperative nonetheless. The instrument will not process any data if the filter ticket is not changed on a daily basis. However, the filter ticket will absorb the particulate matter at a rate dependent upon the instrument's settings. For this particular application, data was collected once every 60 seconds and at a flow rate of 50mL/min to ensure the filter tickets did not need to be changed more than once a day.

The aethalometer draws the air sample through an inlet port, which is typically connected to a small hose as shown in Figure 37. The hose is used because the instrument is not weather proof and provides a greater suction to draw the air sample. Figure 38 shows the 3mm spot that is formed on the ticket after being used.

Figure 37: Aethalometer Obtaining Data

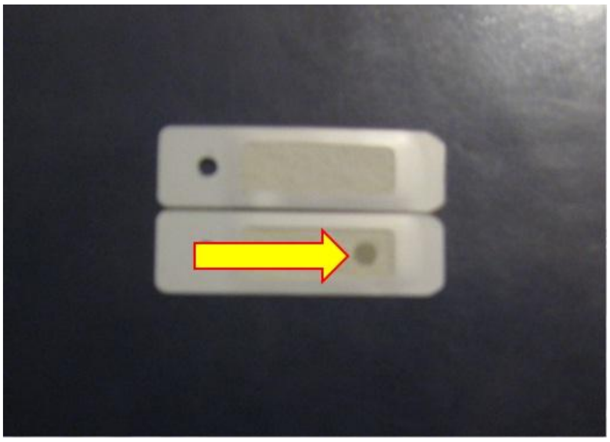

Figure 38: Aethalometer Filters

Once the instrument has collected the data, it is transferred to a computer via USB cable and accessed through a computer program created by Magee Scientific. After the program recognized the device was connected, data could be retrieved, device settings could be modified, graphs of previously collected data could be viewed, or data collection could be viewed in real-time. A Microsoft Excel document, provided by Magee Scientific, was used to conduct further analysis. Table 16 shows an example of the processed BC data, which records the site location, instrument serial number, smoothing parameter, date, time, and the BC level recorded at each time interval. The excel spreadsheet then automatically generates a graph from the recorded data. The graph would show the BC level as it progressed over a 24 hour period and would look like Figure 46.

There is a smoothing parameter which consists of several equations built into the excel template. These equations are meant to make the chart look "nicer." However, these equations were modified when necessary to reduce the "noise" to get a basic understanding of the BC levels present in Venice. After collecting the raw data and inputting it into excel, the data was then transferred into another info-graphic, which can be seen in Figure 45.

The graph in Figure 45 shows the black carbon (BC) concentrations over a 24-hour period and was used to compare the BC level in Venice on different days. A correlation could then be made with the presence of the cruise ships depending on the number of ships on each day. However, the presence of ferries must also be considered. This is due to the difficulty in distinguishing the difference in BC produced by both the cruise ships and ferries. Therefore, ferries will be included in the analysis of the BC present in Venice.

In order to determine the BC present specifically from cruise ships (and ferries), several locations were chosen to compare data. Two methods were chosen to obtain mobile data to understand the BC emissions across the city. The first method was walking from Madonna dell'Orto (position 1) to Piazza San Marco (position 2), then to Piazzale Roma (position 3), and finally back to position 1. This path can be seen in Figure 39. The data collected from this path would yield a baseline for the BC present across the central part of Venice.

Figure 39: Aethalometer Location 1 - Walking

The second method for obtaining mobile data was talking a motoscafo ride around the city. The data collected from this path, as seen in Figure 40, would not only yield a baseline of the emission present around the borders of the island, but also the emissions produced by the smaller boats in Venice.

Figure 40: Aethalomter Location 2 - Motoscafo Ride, Line 41

The third location, shown in Figure 41 and Figure 42, was inside the harbor, which is known as the Marittima. Marco Zanforlin, of the Venezia Terminal Passeggeri, was able to grant the team access to the harbor. This location was used for the bulk of the data measurements. Since the instruments we used are not weatherproof, they needed to be set up at a safe location. However, the instruments also needed to be easily accessible in order to change the filters on daily basis. Figure 43 shows exactly where the aethalometer was placed in the Marittima. This room is only accessible to authorized personnel (VTP workers) and as an emergency exit, which provided the perfect environment to keep the instrument. Figure 44shows where the house was fixed to properly draw in the air. The hose needed to be elevated but also pointing down so that it did not suck in any dirt or water from the rain. Refer to Appendix H - Using the Aethalometer for more pictures on where the instrument was installed.

Figure 41: Aethalometer Location 3 - Marittima

Figure 42: Map of Harbor Location for Aethalometer

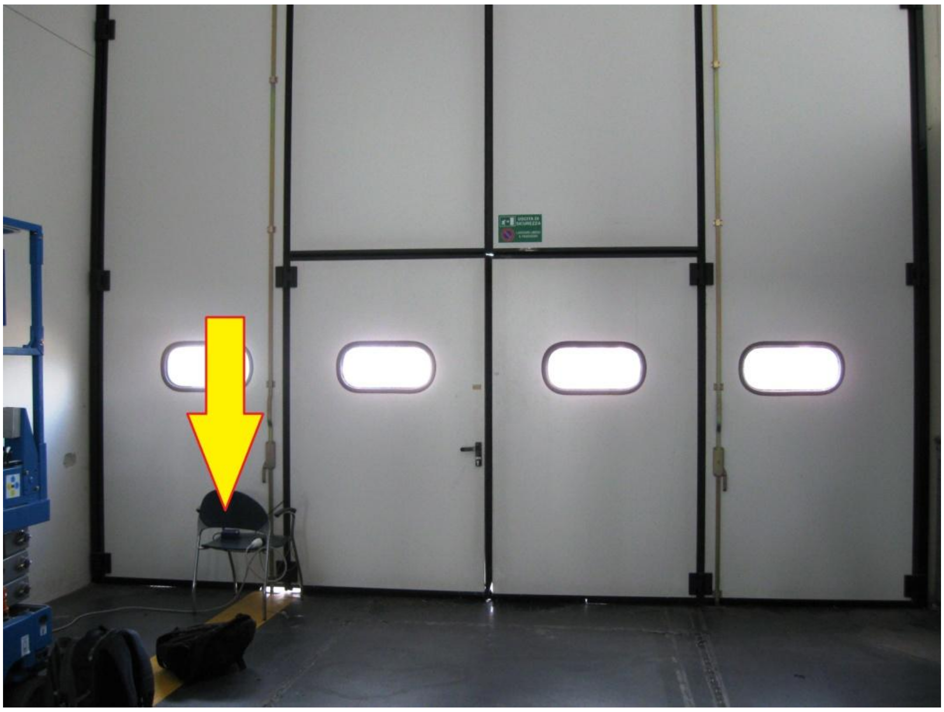

Figure 43: Placement of Aethalometer in the Harbor (1)

Figure 44: Placement of Aethalometer in the Harbor (2)

6.2 Results and Conclusions

Figure 45 compares the BC levels from 11/11/10 to 11/17/10, with the exception of 11/14/10. Data was not obtained on that day because the instrument's filter was not properly changed. Several conclusions can be drawn from this graphic. First, there are significant increases in BC in the morning and evenings. This is due to the arrival and departures of the cruise ships and ferries, whose schedules can be seen in Appendix B - Schedule (Cruise ships and Data Collection). Also, the inversion of the winds and the settling of the atmosphere are the root causes for the increase in the late evening. However, this graph is also a bit puzzling because the number of cruise ships and ferries do not directly correlate with the levels of BC. This is due to the fact that it can take anywhere from 7 to 30 days for the BC to completely settle in the atmosphere.

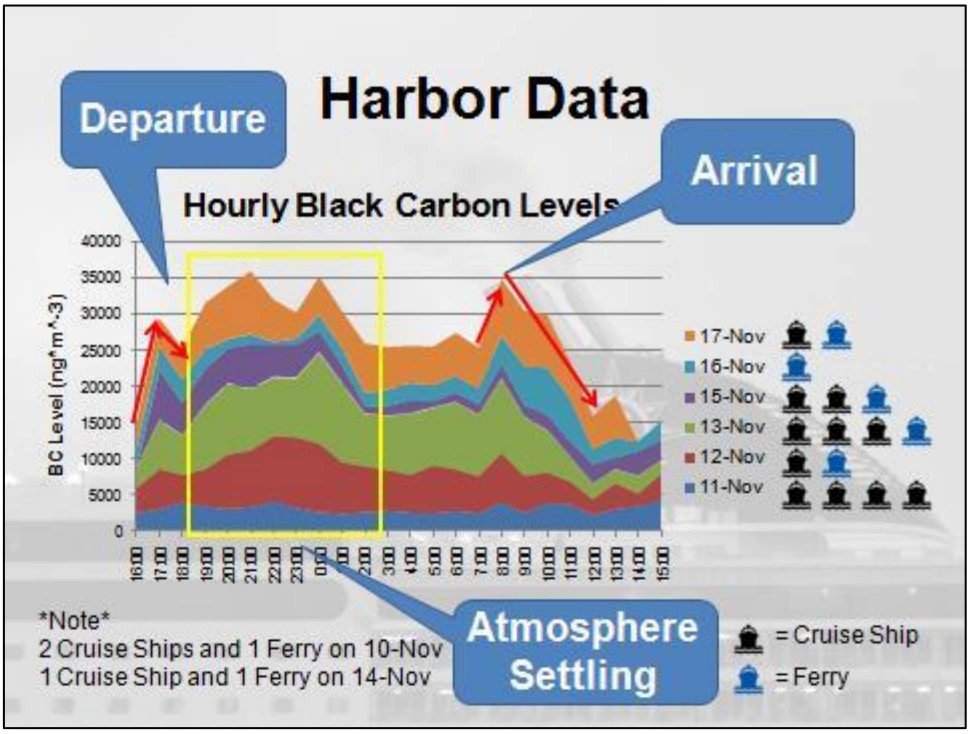

Figure 45: BC Level Comparison Graph

There are several factors that can affect the accuracy of the data collected. These factors include (but are not limited to) the number of cruise ships and ferries present in Venice, the efficiency of their engines, the quality of their fuel, appliances located near the instrument, the wind speed and direction, people smoking near the aethalometer, and land vehicles that may idle near the aethalometer. Generally, if there are more cruise ships and ferries in the harbor then a greater amount of black carbon will be produced. Since black carbon is produced depending on the specific combustion process, the efficiency of the engines and fuel could produce BC emissions that can vary by a factor of 10^6. In addition, appliances, such as for heating and ventilation, that are located near the aethalometer could potentially affect the results. The wind is a contributing factor as well because it can bring emissions from other parts of the harbor and the city itself. Harbor employees and other pedestrians in the harbor may affect the results because the instrument is located directly above a known location for smokers to congregate. Lastly, land taxis, transport trucks and other vehicles are allowed to park directly next to the building where the aethalometer is located. The emissions from the idling vehicles could easily affect the results if they are parked there for a significant amount of time.

Figure 46 shows how the wind can affect the data. The data shows a large peak right before midnight. Using wind data provided for us by the Venezia Terminal Passeggeri, it was determined that the wind was blowing 62.5° at 1.41m/s. This is approximately coming from the Port of Marghera, which generates a considerable amount of pollution (BC). The combination with the atmosphere settling provides a significantly large peak in BC. Figure 47 shows the location of Venice in relation to Port Marghera and Marco Polo Airport, which are two locations that may be responsible for an increase in the pollution levels in Venice. This is due to the operations that occur in these locations, such as vehicle and boat traffic. There is a lot of machinery involved in these operations, which runs on carbonaceous fuel. However, the wind plays a major role in the distribution of the pollution in the atmosphere.

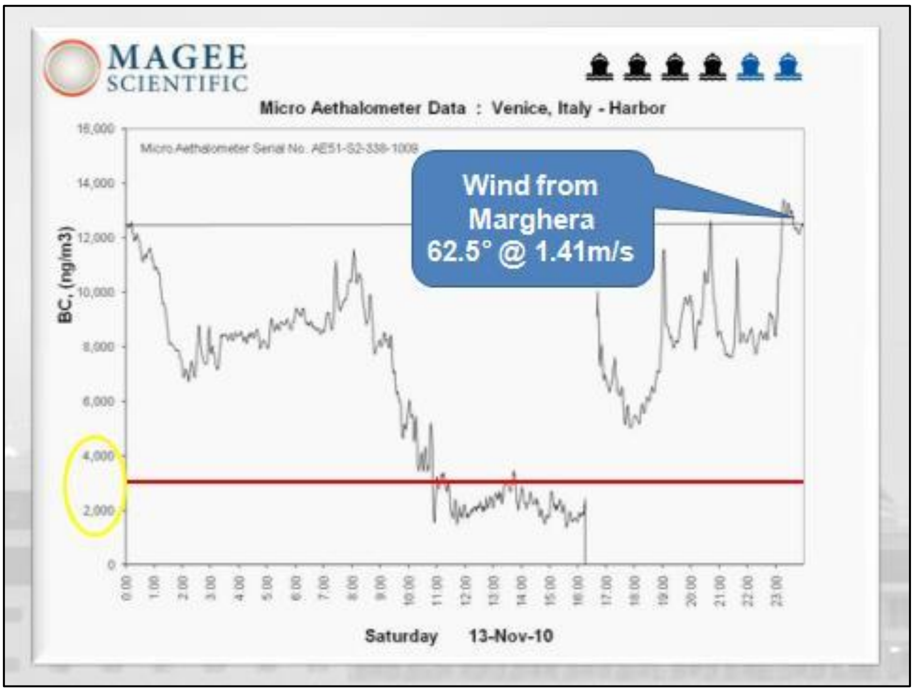

Figure 46: BC Data with Wind Effects

Figure 47: Map of Venice, Porto Marghera and Marco Polo Airport

Figure 48 shows the average of BC present in the Marittima. The three peaks, again, are due to the arriving ferries, departing ferries and the atmosphere settling in the evening.

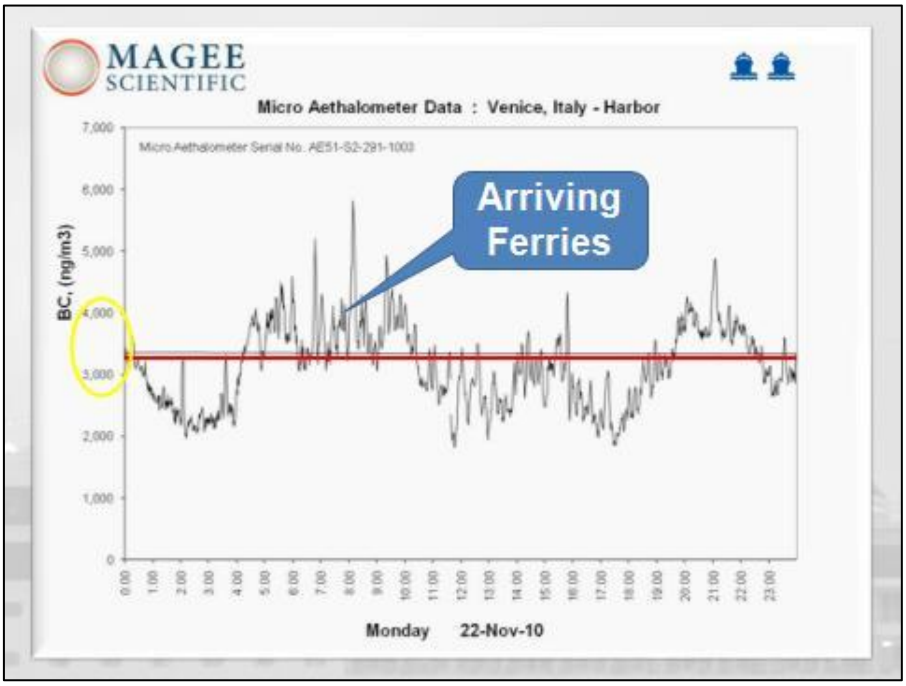

Figure 48: Average BC Level with Cruise Ships/Ferries

Figure 49 shows that the BC levels are significantly lower on 11/30/10. Looking at the schedules for the cruise ships and ferries in Appendix B - Schedule (Cruise ships and Data Collection), it is clear that the rate of cruise ship visits has gone down significantly. The last cruise ship was on 11/27/10, 11/25/10 and then on 11/21/10. Also, only one ferry arrives each day before and on 11/30/10. It can be concluded that the large peak in BC is due to the departing ferry.

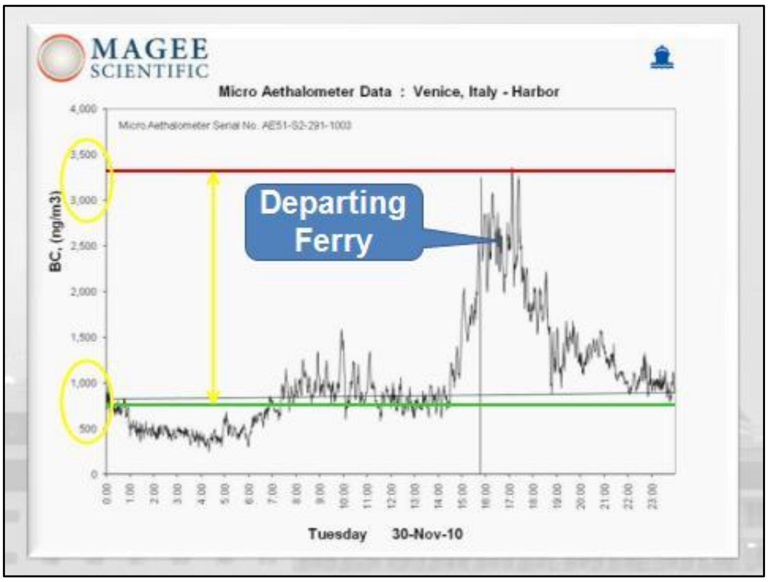

Figure 49: BC with no Cruise Ships

Figure 50 shows the BC present across the central part of Venice on 11/14/10. It can be concluded from this graphic that the average BC in Venice is about 3,200 ng/m^3. The first large peak is when the aethalometer was travelling through Piazzale Roma, picking up the emissions produced by the buses, which is over 200% of the average value of BC across Venice. The second large peak occurs in front of the Ferrovia Vaporetto stop. This is due to the passing Vaporetti and traffic from other small boats. Refer to Figure 100 to view the data graph itself.

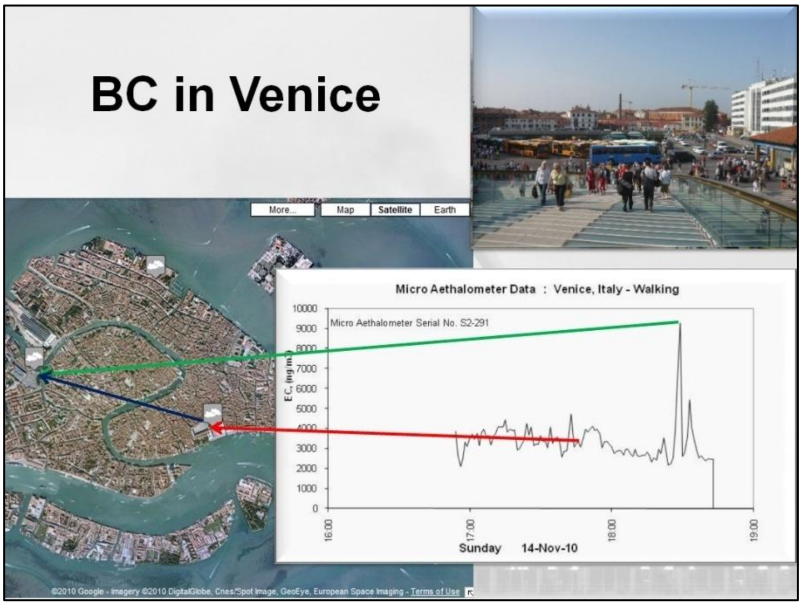

Figure 50: BC Data - Walking (1)

Figure 51 shows a graphic for the BC data during a motoscafo ride around Venice on 11/15/10. There are several peaks when going around the island. There are similar peaks at the Ferrovia stop and Piazzale Roma. However, the largest peak in BC is at the Santa Marta vaporetto stop. This is due to the idling motoscafo, emissions from other boat traffic, and emissions from the nearby cruise ships and ferries.

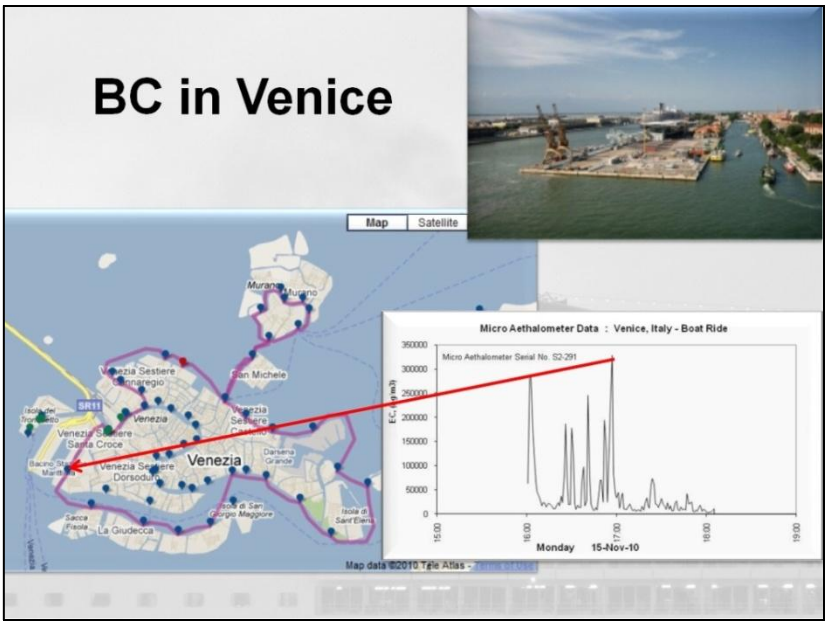

Figure 51: BC Data for Motoscafo Ride (1)

In conclusion, the presence of cruise ships (and ferries) account for approximately a 4.5 times increase in BC in the city of Venice. The BC levels seem to be nearly the same in the Marittima as the rest of Venice. Also, the emissions from the smaller boats are much more pollutant than the emissions from the cruise ships and ferries. This is because the cruise ships are held to higher standards in terms of regulations on their emissions. Also, the aethalometer was much closer to the smaller boats emissions than the cruise ships' and ferries' emissions. Although there is a significant increase in BC with the presence of cruise ships and ferries, the levels do not violate U.S. regulations on the permissible exposure limits to black carbon, which is 3.5 mg/m^3 TWA for OSHA.

6.3 Future Recommendations

Future project groups should contact Jeff Blair (Magee Scientific) immediately during A-term to obtain an aethalometer. Jeff is also a great resource to learn about black carbon and how the aethalometer functions. Unfortunately, Jeff was unable to meet with the team in person. Future groups must set up meetings well in advance to ensure Jeff can schedule time to visit Venice. It is advised to obtain more than one aethalometer. If several aethalometers are acquired, the instruments should be set up at several locations around the city to collect data simultaneously. One of the aethalometers that was used this year was found to have several errors in collecting measurements. Time was lost to conduct a full diagnosis of the instrument and remove erroneous data lines that were produced due to a read/write error in the instrument. It was concluded from the diagnosis that the microAeth Model AE51 must run purely on internal battery to further reduce the "noise" of the data. Therefore, having multiple aethalometers will give more flexibility in conducting data measurements.

Magee Scientific has locations in Berkeley, California, USA and Ljubljana, Slovenia, EU. It is also recommended to contact Grisa Mocnik, who is the director of Aerosol d.o.o in Slovenia. Aerosol d.o.o. provides research and development for Magee Scientific, as well as production of the Aethalometer® instruments, which are sold exclusively by Magee Scientific.

Marco Zanforlin, of the Venezia Terminal Passeggeri, is another person that must be contacted as early as possible. Marco was extremely helpful for this year's project in providing us with access to the Marittima, which is only a small part of the role he played in assisting the team. He is the department head of the Safety, Environment, and Quality Department in addition to working with the Security Department. It cannot be emphasized enough how crucial it is to contact Mr. Zanforlin.

This year's project group made contact with representatives from ARPAV, which is the European version of the Environmental Protection Agency (EPA) in Venice. It is recommended to make contact with Roberto Spinazze and Luisa Vianello. They work with Dr. Enzo Tarabotti at ARPAV, who is the most experienced in measuring particulate emissions in the organization. Collaboration efforts have already begun between the VTP, ARPAV, and Magee Scientific. However, due to time constraints, we were unable to install one of ARPAV's instruments in the Marittima.

Future groups must make contact with members from each organization as soon as possible to get the appropriate instruments in place. The VTP is more than willing to collaborate but needs time to go through the proper procedures to grant ARPAV and Magee access to the VTP facilities. ARPAV has already shown great interest in collaborating with Magee Scientific but requires more information to set up their instruments in accordance with Magee's.

In terms of the methodology, it is recommended that future groups incorporate studying the ferries more thoroughly. Generally, a single ferry will come to Venice each day. There are two lines that usually alternate in arrivals, Anek Lines and Minoan Lines. Visually, it appears that the ferries actually produce more pollution than the cruise ships. This is most likely due to the fact that cruise ships are held to higher standards and regulations. The schedules for both cruise ships and ferries can be found on the VTP's website.

In order to get a full and accurate understanding of the black carbon produced by cruise ships (and ferries), future groups should have a minimum of two aethalometers at their disposal. These instruments should be set up at various locations around Venice. The first location should be in the Marittima to conduct most of the research. However, future groups would get more accurate data if they were able to set up the instrument closer to the cruise ships and at a higher elevation. The other locations should be along the Giudecca Canal, in Piazzale Roma, Piazza San Marco and in an elevated location such as a bell tower. Measurements may only need to be taken for several days but should be taken simultaneously to make accurate comparisons. Data should be collected on days where there a several cruise ships docked and when there are no ships docked.

7. Documenting the Transportation Choices

Venice has a larger population than Skagway, Alaska but it still experiences the effects of the mass influx of people into its harbor. As cruise ships dock in Venice they can unload over 3,000 people at one time. Some days multiple ships can disperse over 13,000 passengers[46]. These are many different ways for these eager passengers to get where they want to go. That destination could be the airport to catch a flight, to the parking lots on Tronchetto or the bus station at Piazzale Roma (the two places in Venice where cars have access) or perhaps to Piazza San Marco. There are a variety of different transportation choices (Figure 52) available to help regulate this traffic flow[47].

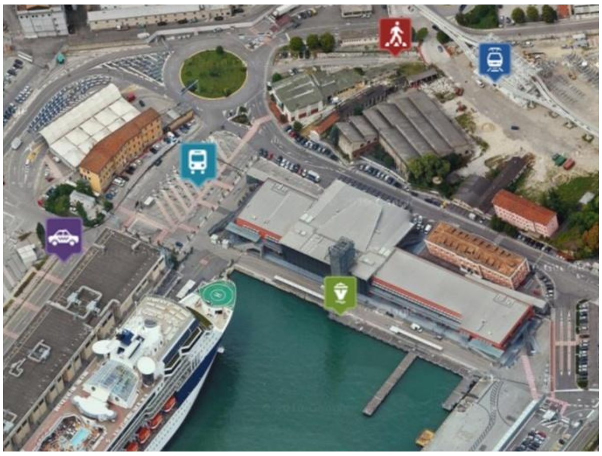

Figure 52: Venice Harbor with Five Different Transportation Choices

People that come off cruise ships can be referred to as accidental tourists. Accidental tourists are people who know very little about the stops their cruise is scheduled for and do not know the layout of the destination. Cruise ship passengers may not know much about Venice and usually if they want to see a Venetian attraction they choose Piazza San Marco[47]. For these transit cruises, cruise ship companies hire lancioni, or water bus shuttles to cart people around the city[47]. When a transit ship stops in the harbor almost every single passenger uses these shuttles and just a few find other means of transportation.

Figure 53: Passengers Walking Out of the Harbor

For turnaround cruise calls, where all of the passengers are disembarking and this is their homeport, there are more transportation options. People can walk from the harbor into Venice (Figure 53). Piazzale Roma is only a fifteen minute walk from the harbor. Piazzale Roma has shuttle buses to take people to the airport or just across the Ponte della Libertà. Also it has vaporetti

[46] "Venice Terminal Passeggeri " http://www.vtp.it/calendario/ricerca.jsp?CercaNave=OK&password=null&CodNave=&CodArmatore=&Giorno=&Mese=&Anno (accessed 9/16/2010, 2010).

[47] "People Mover moves out (sort of)." Apr 22 2010.http://livingveniceblog.com/2010/04/22/peoplemover-moves-out-sort-of/ (accessed Sep 6 2010).

(public water buses) stations and plenty of places to buy tickets. It is also one of two places where people can park cars on Venice proper. People who are not familiar with the layout of Venice may be confused but the walk to Piazzale Roma because there are no clear signs and to get to the main road to walk on passengers must cross a few lines of traffic which constantly have taxis and buses passing through.

Another transportation choice is the people mover. The people mover (Figure 54[48]) is an automated electric tram which connects Tronchetto with the Marittima harbor and the Piazzale Roma. It opened 19 April 2010 but the harbor stop was not opened until 9 June[49]. Two trams are running at the same time with a trip lasting three minutes total. It has a train capacity of 200 people and an hourly capacity of 3,000 people. So for a large cruise ship it would only take an hour to transport all the passengers to Piazzale Roma. It is the first automated aboveground mass transit unit in Italy[50]. The people mover is new to Venice and so its effectiveness has not been documented yet.

Figure 54: People Mover

People movers are great ways to control traffic flow. In the past the region around the harbor port and Piazzale Roma has been disorderly[49]. The amount of people who come through the Venice port has increased by 230%, after cruise ships started becoming more popular[51]. Cruise ships and other large boats have been using the harbor for awhile but the people mover was just built this summer. People movers are useful in the United States making public transportation more organized and time efficient. However in Europe people movers are not as popular with only about 20% of people movers being built in Europe. Usually the reason people movers take so long to build or to get approval to be built is because as forms of public transportation they fall under the city budget. Another reason may be that people are often misinformed about how expensive people movers are to build[52].

Figure 55: Land Taxis

Another transportation option is land taxis and private limousines (Figure 55). Land taxis park near the bus areas and alongside the terminal buildings. These land taxis are mainly for transportation across Ponte della Libertà but some people may use them to

[48] http://www.tourleadervenice.com/2010/04/travel-faster-in-venice-with-the-funicular-people-mover/
[49] "People Mover." http://www.asmvenezia.it/index_eng.html (accessed Sep 20 2010).
[50] "People Mover." Oct 19 2009.http://www.myvenice.org/People-Mover,416.html (accessed Sep 5 2010
[51] Davis, Robert. Marvin, Garry. *Venice: The Tourist Maze*. Berkeley: University of California Press , 2004.
[52] Jakes, Andrew. "Reasons why people movers are underutilized in solving traffic problems." http://justabike.net/PM_Reasons_Paper.pdf (accessed Sep 19 2010).

get to Piazzale Roma since they may be unaware how close Piazzale Roma is to the harbor or may not be aware of the other transportation choices available. Private limos are used to transport people to the airport and can cost €47. Also these taxis and private limos can be used to transport people around Italy for a much larger sum of money.

Figure 56: Alilaguna

At the boat dock there are three different types of boats. First, there is the alilaguna (Figure 56) which is a public transportation shuttle boat which will take people to the Piazza San Marco. The M line goes from the harbor direct to Piazza San Marco for €6.50. A ride to the airport on one of these boats is €15.

Figure 57: Tour Boats

The middle dock is used for shuttle buses that are not part of the alilaguna company. These boats look different and usually are hired by the cruise ships to transport people around the city (Figure 57). These shuttles come throughout disembarking process but do not necessarily have a set schedule.

Figure 58: Water Taxi

The third boat dock is for water taxis. Water taxis (Figure 58)[53] are private boats for 1 to 10 people which will take passengers anywhere in Venice. These water taxis will make the ride around Venice more comfortable but it’s considerably more expensive. A water taxi can range from €100 for 3 people to €130 for 10 people[54]

Figure 59: Bus Station

There are three land bus stations in the Marittima harbor (Figure 59). These are situated near the terminals for easy access for passengers. Buses park here can be reserved for tours around Italy or other European destinations. Also there are buses that take people to the airport and to the mainland across the Ponte della Libertà. The cost to take these buses is usually a few Euros. Lastly there are free shuttle buses available to take people to Piazzale Roma.

[53] http://gallery.nen.gov.uk/image79208.html
[54] "Venice water taxi." 2010.http://www.venicewelcome.com/servizi/taxi/watertaxi.htm (accessed 19 Sep 2010).

7.1 Methodology

The number of people who took each transportation option after disembarking turnaround cruise ships in the Venice harbor was quantified. The different choices studied were: walking, the people mover, land taxis, boats and buses. Tally counters were used to count the number of people for each choice. On days when more than one cruise ship is disembarking there was no way of distinguishing which passengers disembarked from which ship.

Figure 60: Student Counting People Walking and Choosing People Mover

Everyone started counting at a specific time and every fifteen minutes the number of passengers counted for each transportation choice was recorded. Then at a predetermined time everyone stopped counting. One student stood near the people mover and counted the number of passengers either walking or taking the people mover (Figure 60).

Figure 61: Student Counting Buses

Figure 62: Student Counting Land Taxis

Two students were located near the security gate at the entrance of the harbor. Since there were three different places where passengers got on buses, the only location to see the buses from all three stations at the same time was at the gate as they were leaving. In addition, there were several places for people to find taxis, so the gate was the bottleneck point to catch all taxis as they leave. One student counted people on buses (Figure 61) and another student counted passengers in taxis (Figure 62).

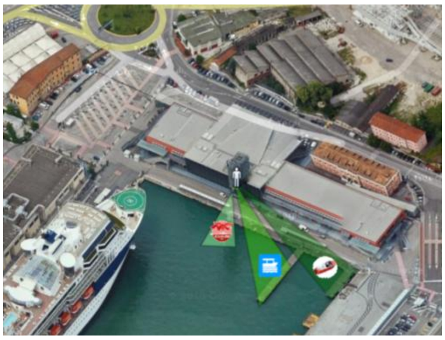

Figure 63: Student Counting Boat Choices

The fourth student stood on the balcony of Terminal 103 overlooking the boat dock (Figure 63). This person counted the total number of people entering the boat dock and the number of people who chose the three different types of boats. The three different types of boats are alilaguna, middle dock (shuttle boats and tour boats) and water taxis.

On Saturday, 6 November, two students stood on the balcony of Terminal 103 overlooking the boats and counted the different types of boats and the number of each type of boat.

Time lapse cameras were set up around the harbor to capture footage of cruise ships docking, disembarking, and the different transportation choices. A time lapse camera was placed near the people mover looking back at the entrance of the harbor to capture footage of people walking out of the terminal and choosing to walk or take the people mover (Figure 64). This camera also captured footage of buses and land taxis leaving the harbor.

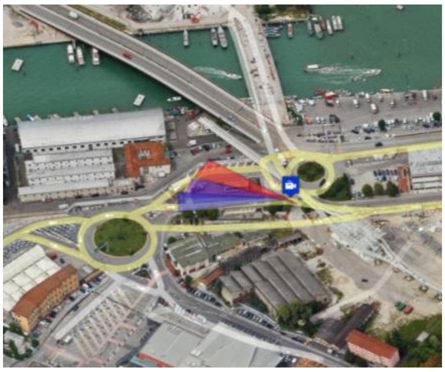

Figure 64: Camera Capturing Passengers Walking, Taking the People Mover, and Land Taxis

Six cameras were set up at different locations and angles of the boat docks (Figure 65). Two of the cameras were set up to capture footage of passengers from a transit cruise ship entering the boat dock and passengers getting on shuttle boats. Four cameras were set up capturing footage of turnaround passengers. Three were placed on the balcony of Terminal 103 and one on the emergency staircase of Terminal 107.

Figure 65: Cameras Capturing Boat Dock

Two time lapse cameras were placed looking at the buses near Terminals 103 and 107 (Figure 66). One camera was placed looking towards the buses from the emergency exit staircase of Terminal 107. Two more cameras were placed in this area overlooking the passengers flowing out of Terminals 107 and 103.

Figure 66: Cameras Capturing Buses and Passengers Leaving Terminals 103 and 107

The locations of signs for different transportation modes were documented and placed in a map to show the concentration of advertisement around the terminals and to see which modes were well labeled.

7.2 Results and Conclusions

Passengers from 14 different turn around cruise ships were counted over five days. A total number of 15,438 passengers were counted. The breakdown per day of how many cruise ships were in port and the number of passengers that were counted can be found in Table 1. The percent of each transportation mode from the total number of passengers counted can be found in Figure 67. All of the time lapse videos can be found on the Vimeo Website.

Table 1: Transportation Choices Overall

Date	Start Time	End Time	Weather	# of CS in Marittima	People Mover	Walking	Bus	Land Taxis/Private Limos	Boats	Total Passengers
10/30/2010	8:45	10:30	Sunny, Cold	5	770	460	2654	1486	1249	**6619**
10/31/2010	9:30	11:00	Rainy, Cool	4	240	130	1787	1391	1041	**4589**
11/1/2010	9:00	10:00	Rainy, Cool	2	97	100	400	62	361	**1020**
11/10/2010	7:45	10:45	Cloudy/ Sunny, Cool	1	179	135	721	161	726	**1922**
11/11/2010	8:00	9:00	Sunny, Cold	2	100	93	497	109	489	**1288**
Overall Total				**14**	**1386**	**918**	**6059**	**3209**	**3866**	**15438**

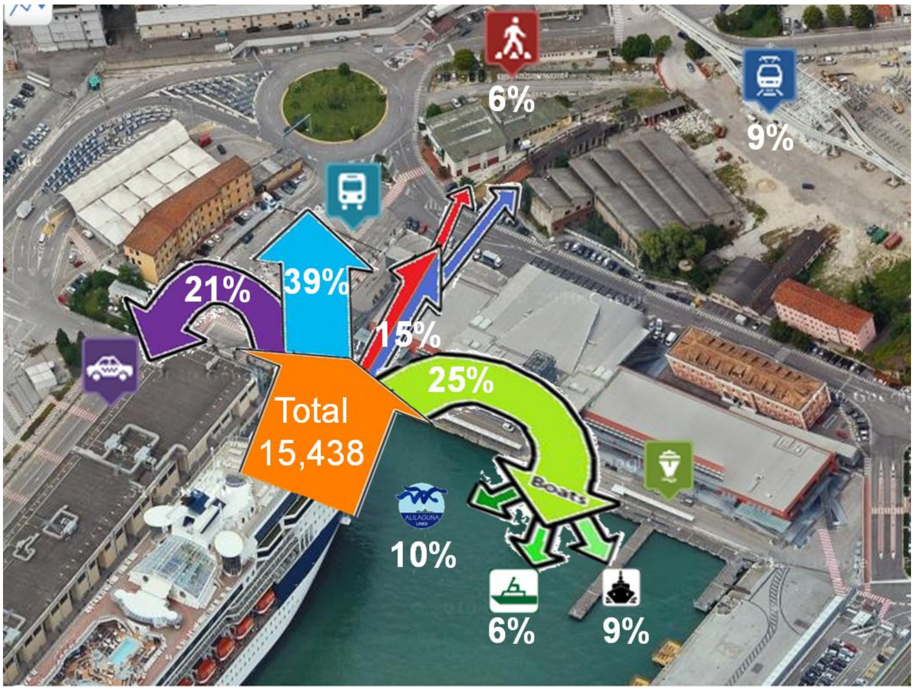

Figure 67: Overall Transportation Choices

A total of 18 signs were counted around Terminals 108, 107, and 103. (Figure 68). These signs helped analyze the popularity of certain transportation choices.

Figure 68: Map of Sign Locations

Table 2: Signs for Transportation Modes

Transportation Choice	Number of Signs
Walking	1
People Mover	3
Land Taxis	4
Boats	8
Buses	2
Total	18

7.2.1Walking

Figure 69: Walking

Walking was not a popular choice. The only feasible destination for walkers was Piazzale Roma (Figure 69). During this time of year, the weather in Venice can be rainy and cold. The thought of walking with luggage in the rain is often not considered. During these cold months not as many people walk especially with the many other transportation choices available.

In addition, the path to Piazzale Roma from the harbor is not well labeled. There is only one sign (Figure 70) and it is a road sign for cars not meant for pedestrians pointing to Piazzale Roma. Also it is dangerous to cross the lanes of traffic on foot since the street is usually busy. If someone did not know the layout of Venice they may get lost trying to walk even though Piazzale Roma is only ten minutes away.

Figure 70: Sign to Piazzale Roma

If people were aware of how close Piazzale Roma was to the exit of the harbor, more people might walk.

7.2.2 People Mover

Figure 72: People Mover Total

The people mover was also not a popular choice (Figure 72). It is a new addition to the transportation choices and a lot of passengers disembarking are unaware of it. An observation made while counting passengers was that many did not know how far into the city the people mover went. Some thought it took passengers to Piazza San Marco, while others thought it would take them to the airport. The people mover was intended to be like a city metro but the distance it covers and the number of stops is not extensive. It has not been used as much as initially intended.

The people mover is not well labeled with very few signs. There are two signs located near the people mover and one located near the entrance of the harbor (Figure 71) which is not near where people walk. These signs are small and hard to read unless you are extremely close to them. If it was labeled better and people knew what it was and where it went, more people would use it.

Figure 71: People Mover Sign

7.2.3 Land Taxis

Figure 73: Taxi Total

Land taxis were also a popular choice with 21% of the total passengers taking cabs from alongside the terminals (Figure 73). Several passengers seemed confused by the buses and assumed that taxis were the only way to get to the mainland. However, on some days the number of taxis was low because less taxi cars came to the harbor on days when less cruise ships were in the harbor.

Land taxis were well labeled right outside the exit of the terminal (Figure 74). Taxi drivers would park outside the exit of the terminals and solicit business. Several passengers also hired private taxis to take them to their destinations before they disembark. Taxis however, can be expensive and so a lot of people choose other forms of transportation.

Figure 74: Land Taxi Sign

7.2.4 Boats

Table 3: Counting of Boat Choices

	Alilaguna	Vaporetti/Middle Dock	Water taxis	Total
31-Oct	561	220	468	1249
6-Nov	594	173	380	1147
10-Nov	126	365	233	724
	1281	**758**	**1081**	**3120**

The boats were a popular choice with 25% of the total number of passengers (Figure 75) because there are several options, and most of the tourists take boats to experience Venice from the water. The boat dock is located close to two of the terminal exits so people see it right as they are leaving (Figure 76). Venice is a unique city with water surrounding it and running through it. People who take boats may be trying to have an authentic Venice experience.

Figure 75: Kiosk to Buy Boat Tickets

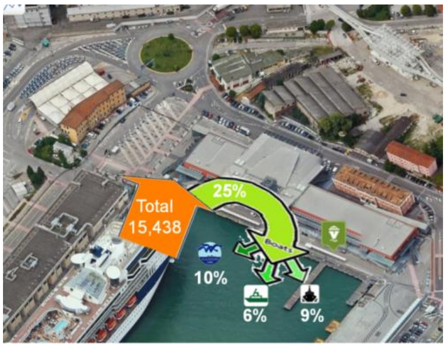

Figure 76: Boats Total

The alilaguna line was very popular, always with a long line because it takes tourists to the most well known parts of the city – and it's cheap. Water taxis were not as popular as the alilaguna because they are expensive but still contribute to 9% of total boat passengers. Water taxis are more private and personal versus the alilaguna and is a better way to travel by boat with a lot of luggage. The middle dock was not as popular because fewer boats use it for planned tours. These are generally ordered ahead of time by certain cruise lines.

Boats were very well labeled with eight signs around the terminal exits (Figure 77). These signs emphasized the destination location of Piazza San Marco and the price. If passengers didn't know how to get to Piazza San Marco from the harbor, they often picked alilaguna since they know this type of transportation will take them there.

Figure 77: Alilaguna Sign

7.2.5 Buses

Figure 78: Buses Total

Buses were the most popular choice with 39% of the total number of passengers (Figure 78) because there are three different bus stations located near every terminal. Buses were an inexpensive way to get to the airport and other places on the mainland across the Ponte della Libertà. It only cost between three and five Euros. There are even free shuttles to Piazzale Roma so people with luggage who do not want to walk or do not want to spend a large amount of money for a boat can get into Venice easily by bus.

Buses were not well labeled with only a few signs near each station (Figure 79) but advertisement was not necessary because the bus terminals are directly outside of each terminal. Also cruise companies set up these buses so they make sure disembarking passengers know where to go.

Figure 79: Bus Parking Sign

A lot of passengers take buses, boats, and taxis because these were readily available in the harbor. Also they are located right outside the terminals and are well labeled. These three transportation modes make up 85% of the total passengers disembarking. Walking and the people mover make people leave the harbor without really knowing where exactly to go since these modes are not well labeled and a lot of people are uncomfortable with the layout of Venice.

7.3 Future Recommendations

More signs should be placed around the harbor to help passengers know which modes of transportation are available to them. The people mover should be more obviously advertised closer to the terminal. In addition, the path to Piazzale Roma should be labeled for pedestrians so they do not have to walk a few hundred meters outside the harbor before seeing a sign pointing them in the right direction.

Marco Zanforlin is an important contact. The harbor is an important location for field work to be conducted so having a contact in the VTP is necessary. Since most cruise ships come at the beginning of November, it is best to contact him early so field work can commence right away.

Consider surveying the nationality of the passengers and their transportation choices. The VTP has noticed a possibility that more Italians walk than Americans and other nationalities because they know more about Venice and its layout. An example of a survey which can be modified to this type of data can be found in the 2009 report Cruise Ships: Influencing the City of Venice. This report can be found on the WPI library database.

Future projects should focus on the passengers' final destinations versus their initial transportation choices. Most cruises have considered "turnaround" stops in Venice, so knowing how many passengers are heading into Venice versus going home or leaving Venice would give us a better understanding about the impact of cruise ships on the overall number of tourists in the city. This could be done by taking personal surveys, simply asking passengers where they intend to visit. Furthermore, students could follow the certain boats and buses to see how many passengers are traveling towards the mainland, such as the Marco Polo Airport. Studies could also consider how many passengers end up in the train station for long-distance travel.

8. Bibliography

2009 CLIA Cruise Market Overview (accessed 9/18/2010).

Apitz, Sabine E., Andrea Barbanti, Martina Bocci, Anna Carlin, Laura Montobbio, and Alberto Giulio Bernstein. 2007. The sediments of the Venice lagoon (Italy) evaluated in a screening risk assessment approach: Part II--lagoon sediment quality compared to hot spots, regional, and international case studies. *Integrated Environmental Assessment & Management* 3 (3) (07): 415-38

Bailey, D., and G. Solomon. "Pollution Prevention at Ports: Clearing the Air." *Environmental Impact Assessment Review* 24.7-8 (2004): 749-74. Web.; p. 751

Bata, Miloslav. "Effects on Buildings of Vibrations Caused by Traffic." *Building Science* 6, no. 4 (12, 1971): 221-246.

Bowman, Frank. "An Integrated Electric Power System: The Next Step." (April 8, 2008) http://www.navy.mil/navydata/cno/n87/usw/issue_9/power_system.html

Buhaug, Ø, Corbett, J.J., Endresen, Ø, Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Markowska, A.Z., Mjelde, A., Nelissen, D., Nilsen, J., P ˚ alsson, C., Winebrake, J.J., Wu, W.-Q., Yoshida, K., 2009. Second IMO GHG study 2009. International Marittima Organization (IMO), London (UK).

Carminati, Eugenio, Silvia Enzi, and Dario Camuffo. "A Study on the Effects of Seismicity on Subsidence in Foreland Basins: An Application to the Venice Area." *Global & Planetary Change* 55, no. 4 (02, 2007): 237-250, http://search.ebscohost.com/login.aspx?direct=true&db=8gh&AN=23741268&site=ehost-live

Campanol, Antonio. Personal Interview. 02/11/2010. 02 Nov 2010.

Coraci, Elisa, Georg Umgiesser, and Roberto Zonta. "Hydrodynamic and Sediment Transport Modelling in the Canals of Venice (Italy)." *Estuarine, Coastal and Shelf Science* 75, no. 1-2 (10, 2007): 250-260.

Cruise Market Watch. "Cruise Market Watch Announces 2010 Cruise Line Market Share and Revenue Projections." http://www.cruisemarketwatch.com/blog1/articles/cruise-market-watch-announces-2010-cruise-line-market-share-and-revenue-projections (accessed 11/21/10).

Davis, Robert. Marvin, Garry. *Venice: The Tourist Maze*. Berkeley: University of California Press , 2004.

Dimentberg, Mikhail. , Edited by Cortney Davis, 2010.

"Dimension Engineering." *A Beginner's Guide to Accelerometers.* N.p.n.d. Web. 11 Dec 2010. http://www.dimensionengineering.com/accelerometers.htm.

Duke University Libraries: Digital Collections. “A Brief History of the Passenger Ship Industry.” http://library.duke.edu/digitalcollections/adaccess/ship-history.html (accessed 11/21/10)

Farrar, C. R., S. W. Doebling, and D. A. Nix. "Vibration-Based Structural Damage Identification " *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 359, no. 1778 (2001): 131 <last_page> 149.

.

F. Schiappa de Azevedo, J. Patricio. "ANNOYANCE AND DAMAGE IN BUILDINGS CAUSED BY VIBRATIONS. CONSIDERATIONS FOR A VIBRATION CONTROL GOOD PRACTICE." *Acustica* 2010, no. 9/18/2010 (2004) (accessed 9/18/2010).\

Jakes, Andrew. "Reasons why people movers are underutilized in solving traffic problems." http://justabike.net/PM_Reasons_Paper.pdf (accessed Sep 19 2010).

Johnson, D. "Environmentally Sustainable Cruise Tourism: A Reality Check." *Marine Policy* 26.4 (2002): 261-70. Web.

Katsioloudis, Petros J. "Green Ships: Keeping Oceans Blue." *The Technology Teacher* 69, no. 5 (-02-01, 2010): 5-9.

Klein, R. A. 2002. *Cruise ship blues: The underside of the cruise ship industry*New Society Pub.

"MarittimaQuest - Daily Event for December 16, 2005 Prinzessin Victoria Luise " http://www.Marittimaquest.com/daily_event_archive/2005/dec/16_prinzessin_victoria_luise.htm (accessed 9/18/2010, 2010).

Marmer, E., F. Dentener, JV Aardenne, F. Cavalli, E. Vignati, K. Velchev, J. Hjorth, F. Boersma, G. Vinken, and N. Mihalopoulos. "What can we Learn about Ship Emission Inventories from Measurements of Air Pollutants Over the Mediterranean Sea?" *Atmospheric Chemistry and Physics Discussions* 9, no. 2 (2009): 7155-7211; p. 7157.

Nogara, Marco. Personal Interview. 19/11/2010. 19 Nov 2010.

"People Mover." http://www.asmvenezia.it/index_eng.html (accessed Sep 20 2010).

"People Mover." Oct 19 2009.http://www.myvenice.org/People-Mover,416.html (accessed Sep 5 2010

"People Mover moves out (sort of)." Apr 22 2010.http://livingveniceblog.com/2010/04/22/peoplemover-moves-out-sort-of/ (accessed Sep 6 2010).

Roughan, John. “The Ocean – Going Stretch Limo.” http://www.nzherald.co.nz/queen-mary-2-giant-of-the-seas/news/article.cfm?c_id=1501162&objectid=10424244 (accessed 11/21/10).

Ship Hydrodynamics, Encyclopedia Britannica <http://www.britannica.com/EBchecked/topic/540904/ship/64197/Ship-hydrodynamics

Skweirczynski, Hunnewell, Reese, Vautrin, "Cruise Ships: Influencing the City of Venice." (2010)

"Summer 09: Destination Focus Europe: Driving Expansion - Cruise Industry News | Cruise News " http://www.cruiseindustrynews.com/cruise-news-articles/67-articles/2892-summer-09-destination-focus-europe-driving-expansion.html (accessed 9/16/2010, 2010).

"Summer 2010: Europe: Growth Market - Cruise Industry News | Cruise News " http://www.cruiseindustrynews.com/cruise-news-articles/67-articles/4198-summer-2010-europe-growth-market.html (accessed 9/16/2010, 2010).

S/S Prinzessin Victoria Luise, Hamburg America Line. (n.d.). Retrieved Dec 15, 2010, from Norway-Heritage: http://www.norwayheritage.com/p_ship.asp?sh=privl

Velchev, K., F. Cavalli, J. Hjorth, E. Marmer, E. Vignati, F. Dentener, and F. Raes. "Ozone Over the Western Mediterranean Sea–results from Two Years of Shipborne Measurements." *Atmospheric Chemistry and Physics Discussions* 10; p. 6130

"Venice Terminal Passeggeri " http://www.vtp.it/calendario/ricerca.jsp?CercaNave=OK&password=null&CodNave=&CodArmatore=&Giorno=&Mese=&Anno (accessed 9/16/2010, 2010).

"Venice water taxi." 2010.http://www.venicewelcome.com/servizi/taxi/watertaxi.htm (accessed 19 Sep 2010).

Zanforlin, Marco. Personal Interview. 11/11/2010. 11 Nov 2010.

9. Appendices

Appendix A - Annotated Bibliography

F. Schiappa de Azevedo, J. Patricio. "ANNOYANCE AND DAMAGE IN BUILDINGS CAUSED BY VIBRATIONS. CONSIDERATIONS FOR A VIBRATION CONTROL GOOD PRACTICE." ***Acustica*** **2010.9/18/2010 (2004)Web. 9/18/2010.**

This article gives basic background information about mechanical waves. The article is important since the vibrations we will be studying are mechanical waves created by the cruise ships. The article will allow us to complete the background section of our report.

"Venice Terminal Passeggeri "Web. 9/16/2010 <http://www.vtp.it/calendario/ricerca.jsp?CercaNave=OK&password=null&CodNave=&CodArmatore=&Giorno=&Mese=&Anno>.

This site gives the schedule for cruise ships in Venice. The article is most important for our report because it provides many facts about how many ships will come in a day, a week, a month and a year. The source gives us great facts to put into our report about the importance of cruise ships to the tourism industry. The web site also allows us to be able to determine the times that we will complete our measurements allowing us to complete our report.

"Summer 2010: Europe: Growth Market - Cruise Industry News | Cruise News "Web. 9/16/2010 <http://www.cruiseindustrynews.com/cruise-news-articles/67-articles/4198-summer-2010-europe-growth-market.html>.

This source gives some basic facts about how fast the cruise ship industry is growing. This article is important for the introduction of our report to provide a sense of the importance of cruise ships to the tourism industry.

Bata, Miloslav. "Effects on Buildings of Vibrations Caused by Traffic." ***Building Science*** **6, no. 4 (12, 1971): 221-246.**

The article talks about the different kinds of waves that can cause damage, and how to measure them. The article also gives some numbers on how much is too much for a wave speed. This source will be good for the methodology section of our report.

Velchev, K., F. Cavalli, J. Hjorth, E. Marmer, E. Vignati, F. Dentener, and F. Raes. "Ozone Over the Western Mediterranean Sea–results from Two Years of Shipborne Measurements." Atmospheric Chemistry and Physics Discussions 10, (.

This article will be a good methodological source because it describes the different types of monitoring equipment used to conduct measurements:

(1) UV Photometric Ozone Analyzer (Model C49 Thermo Electron Instruments Inc., 20 USA), (2) Aerosol Black Carbon Analyzer (Aethalometer, AE 21, 2 wavelengths, MageeScientific, USA), (3) Optical Aerosol Spectrometer (GRIMM Model 1.109, GRIMM Aerosol TechnikGmbH, Germany).

This gives us insight into which instruments we should obtain to make our measurements. The article also discusses the ideal locations to measure the various air pollutants. As well as referring to the data from this article, the graphics will give us a good idea on the kinds of graphics we should be using. With this information, we can start to write our methodology on how we will be studying

Johnson, D. "Environmentally Sustainable Cruise Tourism: A Reality Check." *Marine Policy* 26.4 (2002): 261-70. Web.

This article outlines the environmental considerations that need to be addressed with Cruise Ship Tourism. It discusses environmental sustainability strategies and the measures that the tourists, cruise liner operators, and destinations can follow to ensure their sustainable development obligations are met. It also analyzes the impacts that cruise tourism has on the environment. They stress the fact that tourists fail to realize that they have an obligation, as consumers, to ensure environmental improvements are made. This article will help us to understand the environmental impacts caused by cruise ship tourism and identify the sustainable strategies that the cruise liners should be following.

Klein, R. A. *Cruise Ship Blues: The Underside of the Cruise Ship Industry*. New Society Pub, 2002. google. Web.

This book gives an overview of the cruise ship industry and the progress it has made. It discusses how passengers are often misled about the cruise experience. The author also goes into detail about the “Alaska Cruise Ship Initiative,” and how governments are trying to enforce regulations to comply with environmental sustainability standards. Numerous examples are provided to show how certain cruise ships were found violating such regulations and any penalties that may have went along with punishing the cruise liners. Our group can use this reference in our project to gain a better understanding of how the cruise ship industry operates and how certain regulations came to be.

Bailey, D., and G. Solomon. "Pollution Prevention at Ports: Clearing the Air." *Environmental Impact Assessment Review* 24.7-8 (2004): 749-74. Web.

This article describes, in detail, the effects of air pollution in seaports. The author lists the different types of air pollutants present in seaports and the direct causes of the pollutants. Also, the article identifies different methods of reducing the harmful pollutants and the amount of effort and finances that would go into the prevention process. This reference will benefit our project because it gives us insight into which pollutants we should be looking for in Venice and will help us explain the significance of the types of pollutants we will be measuring.

"Cruise passengers (and there're a lot of you), rejoice and be moved." ***Living Venice Blog*****. N.p., 9 Jun 2010. Web. 06 Sep 2010. <http://livingveniceblog.com/tag/peoplemover/>.**

This site gives basic information on the people mover in Venice. It gives the hours of operation which will be useful in Venice. Since the people mover is so new there are only blogs and other similar sites with information. This site was used for the background chapter.

"People Mover." My Venice. N.p., 19 Oct 2009. Web. 06 Sep 2010. <http://www.myvenice.org/People-Mover,416.html>.

This site contained information on the people mover. It had details about its travel time, how many trains there were and the hourly capacity. The information found on this website was used in the background chapter. This site shows that the people mover can be helpful to people who want to make the short trip from the harbor to Piazzala Roma in a very short amount of time.

Kelpšaite, L., and T. Soomere. "Vessel-Wave Induced Potential Longshore Sediment Transport at Aegna Island, Tallinn Bay " ***Estonian Journal of Engineering*** **15.3 (2009): 168.** ***DOI.*** **Web.**

This article outlines a possible hydrodynamic effect of large vessels on longshore islands, which can be easily compared to the tight waterways of Venice. Our main concern is whether or not increasing hydrodynamic flux, or volumetric flow of canals can be damaging to their structure. However, this article brings up a valid point- what if the increased flow affects the sediment levels?

Copeland, C. "Cruise Ship Pollution: Background, Laws and Regulations, and Key Issues." ***Water Pollution Issues and Developments*** **(2008): 1. Web.**

This article outlines the specifics regarding cruise ship pollution regulations. Simply put, if our research proves the cruise liners breaking these laws, there can be some serious positive and negative social implications. This article could also shed light on possible methodologies on pollution measurement. Even if their pollution in Venice is within regulations, it will still be important to get a strong idea of their actual levels.

Jakes, Andrew. "Reasons why people movers are underutilized in solving traffic problems." http://justabike.net/PM_Reasons_Paper.pdf (accessed Sep 19 2010).

This source provides the definition of a people mover and why they are not being used as much as they should be. It also provides some statistics about where in the world people movers are being built more and the cost of building a people mover.

"People Mover." http://www.asmvenezia.it/index_eng.html (accessed Sep 20 2010).

This source provides information about why the people mover in Venice was constructed. Also its says the Venice people mover is an electronic automatic tram. It also provides the available hours which will be important when we are over in Venice.

"People Mover moves out (sort of)." Apr 22 2010.http://livingveniceblog.com/2010/04/22/peoplemover-moves-out-sort-of/ (accessed Sep 6 2010).

This source is excellent even though it comes from a blog because it describes other forms of transportation people use when disembarking from cruise ships. It also talks about how the people mover is helpful with the traffic flow created by the cruise ships and also how helpful the people mover is to Venetians who have to travel to Tronchetto.

Coraci, Elisa, Georg Umgiesser, and Roberto Zonta. "Hydrodynamic and Sediment Transport Modelling in the Canals of Venice (Italy)." ***Estuarine, Coastal and Shelf Science*** **75, no. 1-2 (10, 2007): 250-260.**

This article gives a lot of insight on specifics regarding the hydrodynamics of the canals in Venice. It discusses the transport of sediment when water is disturbed, and outlines canals which experience deposition and erosion. It also explains the sea-like nature of the Venice Lagoon and why the Adriatic Sea has such a heavy impact on the island itself.

Appendix B - Schedule (Cruise ships and Data Collection)

Table 4: Cruise Ship Schedule

Date	Arrival	Departure	Ship Name	Zone	Terminal
30/10/2010	0:00	0:00	NAUTICA	SAN BASILIO	San Basilio
30/10/2010	9:00	18:00	COSTA VICTORIA	MARITTIMA	107
30/10/2010	7:30	17:00	NORWEGIAN GEM	MARITTIMA	108
30/10/2010	12:00	0:00	QUEEN VICTORIA	RIVA SETTE MARTIRI	
30/10/2010	9:00	17:00	MSC MAGNIFICA	MARITTIMA	Isonzo
30/10/2010	6:00	0:00	VISION OF THE SEAS	MARITTIMA	117
30/10/2010	6:30	17:15	SPLENDOUR OF THE SEAS	MARITTIMA	103
30/10/2010	7:00	17:00	SEABOURN SPIRIT	SAN BASILIO	San Basilio
31/10/2010	0:00	11:00	VISION OF THE SEAS	MARITTIMA	
31/10/2010	0:00	21:00	QUEEN VICTORIA	MARITTIMA	108
31/10/2010	8:30	18:00	MSC MUSICA	MARITTIMA	Isonzo
31/10/2010	10:00	18:00	COSTA SERENA	MARITTIMA	107
31/10/2010	0:00	22:00	NAUTICA	SAN BASILIO	
31/10/2010	7:30	17:00	ASTOR	MARITTIMA	103
1/11/2010	9:00	17:00	COSTA FORTUNA	MARITTIMA	107
1/11/2010	7:30	0:00	GRAND CELEBRATION	MARITTIMA	117
2/11/2010	0:00	17:00	GRAND CELEBRATION	MARITTIMA	
3/11/2010	9:00	17:00	MSC OPERA	MARITTIMA	Isonzo
5/11/2010	13:30	0:00	BRILLIANCE OF THE SEAS	MARITTIMA	
5/11/2010	14:00	0:00	AZAMARA QUEST	SAN BASILIO	
6/11/2010	0:00	0:00	AZAMARA QUEST	SAN BASILIO	San Basilio

6/11/2010	0:00	14:00	BRILLIANCE OF THE SEAS	MARITTIMA	
6/11/2010	9:00	17:00	MSC MAGNIFICA	MARITTIMA	Isonzo
6/11/2010	7:00	17:00	SEABOURN ODYSSEY	MARITTIMA	103
6/11/2010	6:45	17:00	SPLENDOUR OF THE SEAS	MARITTIMA	117
6/11/2010	9:00	18:00	COSTA VICTORIA	MARITTIMA	107
7/11/2010	0:00	14:00	AZAMARA QUEST	SAN BASILIO	
7/11/2010	10:00	18:00	COSTA SERENA	MARITTIMA	107
8/11/2010	9:00	17:00	COSTA FORTUNA	MARITTIMA	107
9/11/2010	13:00	0:00	STAR PRINCESS	MARITTIMA	
9/11/2010	8:00	0:00	INSIGNIA	SAN BASILIO	
10/11/2010	0:00	0:00	INSIGNIA	SAN BASILIO	San Basilio
10/11/2010	0:00	0:00	STAR PRINCESS	MARITTIMA	108
11/11/2010	0:00	13:00	STAR PRINCESS	MARITTIMA	
11/11/2010	6:00	18:00	VISION OF THE SEAS	MARITTIMA	Isonzo
11/11/2010	4:00	21:00	PACIFIC PRINCESS	MARITTIMA	103
11/11/2010	0:00	18:00	INSIGNIA	SAN BASILIO	
12/11/2010	10:00	18:00	AMADEA	MARITTIMA	
13/11/2010	9:00	17:00	COSTA VICTORIA	MARITTIMA	107
13/11/2010	9:00	17:00	MSC MAGNIFICA	MARITTIMA	Isonzo
13/11/2010	6:45	17:00	SPLENDOUR OF THE SEAS	MARITTIMA	117
14/11/2010	10:00	18:00	COSTA SERENA	MARITTIMA	107
15/11/2010	9:00	17:00	COSTA FORTUNA	MARITTIMA	107
15/11/2010	8:00	17:00	QUEEN ELIZABETH	MARITTIMA	
17/11/2010	8:00	0:00	DEUTSCHLAND	SAN BASILIO	

18/11/2010	0:00	16:00	DEUTSCHLAND	SAN BASILIO	
18/11/2010	9:00	0:00	ATHENA	MARITTIMA	108
19/11/2010	0:00	12:00	ATHENA	MARITTIMA	
20/11/2010	9:00	17:00	MSC MAGNIFICA	MARITTIMA	Isonzo
20/11/2010	6:45	17:00	SPLENDOUR OF THE SEAS	MARITTIMA	117
21/11/2010	10:00	17:00	COSTA SERENA	MARITTIMA	107
25/11/2010	9:00	17:00	MSC OPERA	MARITTIMA	Isonzo
27/11/2010	9:00	16:00	MSC MAGNIFICA	MARITTIMA	Isonzo
8/12/2010	9:00	16:00	MSC MAGNIFICA	MARITTIMA	Isonzo

Table 5: Ferry Schedule

Date	Arrival	Departure	Ship Name	Ferry Line	Terminal
30/10/2010	9:00	17:00	OLYMPIA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
30/10/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
31/10/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
1/11/2010	9:00	17:00	EUROPA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
2/11/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
3/11/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
5/11/2010	9:00	14:00	EUROPA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
6/11/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
7/11/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
8/11/2010	9:00	17:00	EUROPA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
9/11/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123

10/11/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
12/11/2010	9:00	14:00	EUROPA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
13/11/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
14/11/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
15/11/2010	9:00	17:00	EUROPA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
16/11/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
17/11/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
19/11/2010	9:00	14:00	EUROPA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
20/11/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
21/11/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
22/11/2010	9:00	17:00	EUROPA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
23/11/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
24/11/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
26/11/2010	9:00	14:00	EUROPA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
27/11/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
28/11/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
29/11/2010	9:00	17:00	EUROPA PALACE	MINOAN LINES SA SHIPPING COMPANY	123
30/11/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
1/12/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
4/12/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
5/12/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123
6/12/2010	9:00	17:00	OLYMPIA PALACE	MINOAN LINES SA SHIPPING COMPANY	123

7/12/2010	7:30	13:00	LEFKA ORI	ANEK LINES S.A.	123
8/12/2010	7:30	13:00	SOPHOCLES V.	ANEK LINES S.A.	123

Table 6: Combined Cruise Ship and Ferry Schedule

Date	Arrival	Departure	Ship Name	Zone	Terminal
30/10/2010	0:00	0:00	NAUTICA	SAN BASILIO	San Basilio
30/10/2010	9:00	18:00	COSTA VICTORIA	MARITTIMA	107
30/10/2010	7:30	17:00	NORWEGIAN GEM	MARITTIMA	108
30/10/2010	12:00	0:00	QUEEN VICTORIA	RIVA SETTE MARTIRI	
30/10/2010	9:00	17:00	MSC MAGNIFICA	MARITTIMA	Isonzo
30/10/2010	6:00	0:00	VISION OF THE SEAS	MARITTIMA	117
30/10/2010	6:30	17:15	SPLENDOUR OF THE SEAS	MARITTIMA	103
30/10/2010	7:00	17:00	SEABOURN SPIRIT	SAN BASILIO	San Basilio
30/10/2010	9:00	17:00	MINOAN LINES	MARITTIMA	123
30/10/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
31/10/2010	0:00	11:00	VISION OF THE SEAS	MARITTIMA	
31/10/2010	0:00	21:00	QUEEN VICTORIA	MARITTIMA	108
31/10/2010	8:30	18:00	MSC MUSICA	MARITTIMA	Isonzo
31/10/2010	10:00	18:00	COSTA SERENA	MARITTIMA	107
31/10/2010	0:00	22:00	NAUTICA	SAN BASILIO	
31/10/2010	7:30	17:00	ASTOR	MARITTIMA	103
31/10/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
1/11/2010	9:00	17:00	COSTA FORTUNA	MARITTIMA	107
1/11/2010	7:30	0:00	GRAND CELEBRATION	MARITTIMA	117

1/11/2010	9:00	17:00	MINOAN LINES	MARITTIMA	123
2/11/2010	0:00	17:00	GRAND CELEBRATION	MARITTIMA	
2/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
3/11/2010	9:00	17:00	MSC OPERA	MARITTIMA	Isonzo
3/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
5/11/2010	13:30	0:00	BRILLIANCE OF THE SEAS	MARITTIMA	
5/11/2010	14:00	0:00	AZAMARA QUEST	SAN BASILIO	
5/11/2010	9:00	14:00	MINOAN LINES	MARITTIMA	123
6/11/2010	0:00	0:00	AZAMARA QUEST	SAN BASILIO	San Basilio
6/11/2010	0:00	14:00	BRILLIANCE OF THE SEAS	MARITTIMA	
6/11/2010	9:00	17:00	MSC MAGNIFICA	MARITTIMA	Isonzo
6/11/2010	7:00	17:00	SEABOURN ODYSSEY	MARITTIMA	103
6/11/2010	6:45	17:00	SPLENDOUR OF THE SEAS	MARITTIMA	117
6/11/2010	9:00	18:00	COSTA VICTORIA	MARITTIMA	107
6/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
7/11/2010	0:00	14:00	AZAMARA QUEST	SAN BASILIO	
7/11/2010	10:00	18:00	COSTA SERENA	MARITTIMA	107
7/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
8/11/2010	9:00	17:00	COSTA FORTUNA	MARITTIMA	107
8/11/2010	9:00	17:00	MINOAN LINES	MARITTIMA	123
9/11/2010	13:00	0:00	STAR PRINCESS	MARITTIMA	
9/11/2010	8:00	0:00	INSIGNIA	SAN BASILIO	
9/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
10/11/2010	0:00	0:00	INSIGNIA	SAN BASILIO	San Basilio

10/11/2010	0:00	0:00	STAR PRINCESS	MARITTIMA	108
10/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
11/11/2010	0:00	13:00	STAR PRINCESS	MARITTIMA	
11/11/2010	6:00	18:00	VISION OF THE SEAS	MARITTIMA	Isonzo
11/11/2010	4:00	21:00	PACIFIC PRINCESS	MARITTIMA	103
11/11/2010	0:00	18:00	INSIGNIA	SAN BASILIO	
12/11/2010	10:00	18:00	AMADEA	MARITTIMA	
12/11/2010	9:00	14:00	MINOAN LINES	MARITTIMA	123
13/11/2010	9:00	17:00	COSTA VICTORIA	MARITTIMA	107
13/11/2010	9:00	17:00	MSC MAGNIFICA	MARITTIMA	Isonzo
13/11/2010	6:45	17:00	SPLENDOUR OF THE SEAS	MARITTIMA	117
13/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
14/11/2010	10:00	18:00	COSTA SERENA	MARITTIMA	107
14/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
15/11/2010	9:00	17:00	COSTA FORTUNA	MARITTIMA	107
15/11/2010	8:00	17:00	QUEEN ELIZABETH	MARITTIMA	
15/11/2010	9:00	17:00	MINOAN LINES	MARITTIMA	123
16/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
17/11/2010	8:00	0:00	DEUTSCHLAND	SAN BASILIO	
17/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
18/11/2010	0:00	16:00	DEUTSCHLAND	SAN BASILIO	
18/11/2010	9:00	0:00	ATHENA	MARITTIMA	108
19/11/2010	0:00	12:00	ATHENA	MARITTIMA	
19/11/2010	9:00	14:00	MINOAN LINES	MARITTIMA	123

20/11/2010	9:00	17:00	MSC MAGNIFICA	MARITTIMA	Isonzo
20/11/2010	6:45	17:00	SPLENDOUR OF THE SEAS	MARITTIMA	117
20/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
21/11/2010	10:00	17:00	COSTA SERENA	MARITTIMA	107
21/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
22/11/2010	9:00	17:00	MINOAN LINES	MARITTIMA	123
23/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
24/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
25/11/2010	9:00	17:00	MSC OPERA	MARITTIMA	Isonzo
26/11/2010	9:00	14:00	MINOAN LINES	MARITTIMA	123
27/11/2010	9:00	16:00	MSC MAGNIFICA	MARITTIMA	Isonzo
27/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
28/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
29/11/2010	9:00	17:00	MINOAN LINES	MARITTIMA	123
30/11/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
1/12/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
4/12/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
5/12/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
6/12/2010	9:00	17:00	MINOAN LINES	MARITTIMA	123
7/12/2010	7:30	13:00	ANEK LINES	MARITTIMA	123
8/12/2010	9:00	16:00	MSC MAGNIFICA	MARITTIMA	Isonzo
8/12/2010	7:30	13:00	ANEK LINES	MARITTIMA	123

Table 7: Data Collection Schedule

Mon Oct 25	6am – 6pm	Le Boreal
	6am – 6:30pm	Field Trial Day
	8am – 5pm	Thompson Spirit
	8:30am – 6pm	Arcadia
	9am – 5pm	Costa Fortuna
Tue Oct 26	11am – 12pm	Vibrations
	11am – 12pm	Hydrodynamics
	12pm – 1pm	Transportation
	12pm – 11pm	Minerva
Wed Oct 27	»11pm	Minerva
	7am – 8am	Vibrations
	7am – 8am	Hydrodynamics
	8am – 9am	Transportation
	8am – 8pm	Vistamar
Fri Oct 29	6:30am – 7:30am	Vibrations
	6:30am – 7:30am	Hydrodynamics
	7:30am – 8:30am	Transportation
	7:30am – 4pm	Orient Queen
	9am – 10pm	Nautica
Sat Oct 30	All day	Nautica
	5:30am – 6:30am	Vibrations
	5:30am – 6:30am	Hydrodynamics
	6am – 11am	Vision of The Seas
	6:30am – 7:30am	Transportation
	6:45am – 5pm	Splendour of The Seas
	7am – 5pm	Seabourn Spirit
	7:30am – 5pm	Norwegian Gem
	9am – 5pm	MSC Magnifica
	9am – 6pm	Costa Victoria
	12pm – 9pm	Queen Victoria
Sun Oct 31	»10pm	Nautica

		»11am	Vision of The Seas
		»9pm	Queen Victoria
		6:30am – 7:30am	Vibrations
		6:30am – 7:30am	Hydrodynamics
		7:30am – 8:30am	Transportation
		7:30am – 5pm	Astor
		8:30am – 6pm	MSC Musica
		10am – 6pm	Costa Serena
Mon Nov 1		7:30am – 5pm	Grand Celebration
		8am – 9am	Vibrations
		8am – 9am	Hydrodynamics
		9am – 10am	Transportation
		9am – 5pm	Costa Fortuna
Tue Nov 2		»5pm	Grand Celebration
Wed Nov 3		7:30am – 8:30am	Hydrodynamics
		7:30am – 8:30am	Vibrations
		9am – 5pm	MSC Opera
Fri Nov 5		12pm – 1pm	Vibrations
		12pm – 1pm	Hydrodynamics
		1pm – 2pm	Transportation
		1:30pm – 2pm	Brilliance of The Seas
		2pm – 2pm	Azamara Quest
Sat Nov 6		»2pm	Brilliance of The Seas
		All day	Azamara Quest
		5:30am – 6:30am	Vibrations
		5:30am – 6:30am	Hydrodynamics
		6:45am – 5pm	Splendour of The Seas
		7am – 8am	Transportation
		7am – 5pm	Seabourn Odyssey
		7am – 5pm	Seabourn Odyssey
		9am – 5pm	MSC Magnifica
		9am – 6pm	Costa Victoria

Sun Nov 7	»2pm	Azamara Quest
	8am – 9am	Tentative Start of Particulates Field Work
	10am – 6pm	Costa Serena
Mon Nov 8	9am – 5pm	Costa Fortuna
Tue Nov 9	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	8am – 6pm	Insignia
	1pm – 1pm	Star Princess
Wed Nov 10	All day	Insignia
	All day	Star Princess
	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
Thu Nov 11	»6pm	Insignia
	»1pm	Star Princess
	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
Fri Nov 12	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	10am – 6pm	Amedea
Sat Nov 13	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	6:45am – 5pm	Splendour of The Seas
	9am – 5pm	MSC Magnifica
	9am – 5pm	Costa Victoria
Sun Nov 14	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	10am – 6pm	Costa Serena
Mon Nov 15	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	8am – 5pm	Queen Elizabeth
	9am – 5pm	Costa Fortuna
Tue Nov 16	12pm – 1pm	WPI VPC Ships Team: Meet with Jeff Blair -

		Venice, Italy
Wed Nov 17	All day	WPI VPC Ships Team: Meet with Jeff Blair - Venice, Italy
	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	8am – 4pm	Deutschland
Thu Nov 18	»1pm	WPI VPC Ships Team: Meet with Jeff Blair - Venice, Italy
	»4pm	Deutschland
	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	9am – 12pm	Athena
Fri Nov 19	»12pm	Athena
Sat Nov 20	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	6:45am – 5pm	Splendour of The Seas
	9am – 5pm	MSC Magnifica
Sun Nov 21	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	10am – 5pm	Costa Serena
Wed Nov 24	7am – 8am	Tentative End of Particulate Field Work
Thu Nov 25	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	9am – 5pm	MSC Opera
Sat Nov 27	4am – 5:30am	Continue work on Hydrodynamics, Transportation and Vibrations as needed
	9am – 4pm	MSC Magnifica
	4pm – 5pm	End of Field Work
Wed Dec 1	12pm – 1pm	Finalize Background
	1pm – 5:30pm	Analysis of Field Testing
Thu Dec 2	12pm – 1pm	Finalize Introduction
	1pm – 5:30pm	Analysis of Field Testing

Fri Dec 3-16	12pm – 5:30pm	Analysis of Filed Testing
Sat Dec 4-16	12pm – 5:30pm	Conclusions and Recommendations

Appendix C - Budget

Table 8: Project Budget

Description	Price
Project Log: Binders, page dividers, paper, etc.	$40
Venice Report	$23
Time lapse camera	$120
Heavy duty scissors and stapler	$20
WPI Apparel for Collaborators	$75
Refreshments for Final Presentation	$18
Total	$278

Appendix D - Size and Age of Cruise Ships

Table 9: Size and Age of Cruise Ships

Size		**Age**	
Large (over 50,000 tons)	**Small (under 50,000 tons)**	**Old (1985-2003)**	**New (2004- 2010)**
Quenn Elizabeth	Minerva	Minerva	Vistamar
Star Princess	Vistamar	Nautica	Orient Queen
MSC Magnifica	Nautica	Vision of the Seas	Queen Victoria
Costa Serna	Orient Queen	Splendour of the seas	MSC Musica
Costa Fortuna	Astor	Astor	Grand Celebration
MSC Opera	Seabourn spirit	Seabourn spirit	Quenn Elizabeth
Brilliance of the seas	Grand Celebration	Costa Victoria	Athena
Norwegian Gem	Azamara Quest	Costa Fortuna	Arcadia
Costa Victoria	seabourn odyssey	Brilliance of the seas	Le Boreal
MSC Musica	Insignia	Insignia	Azamara Quest
Vision of the Seas	Pacific Princess	Star Princess	seabourn odyssey
Queen Victoria	Amedea	Pacific Princess	MSC Magnifica
Splendour of the seas	Deutschland	Amedea	Costa Serna
	Athena	Deutschland	Norwegian Gem
			MSC Opera

Appendix E - Y and Z Acceleration Graphs

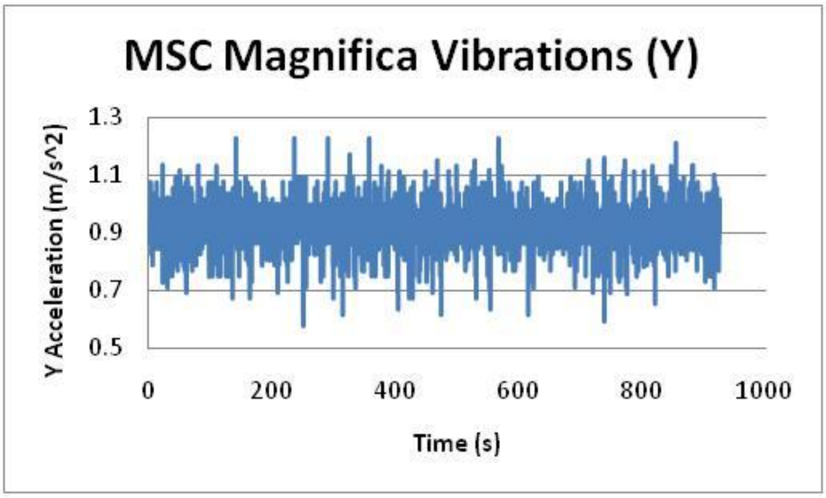

Figure 80: *MSC Magnifica* at Zattere (Y) (11-20-2010)

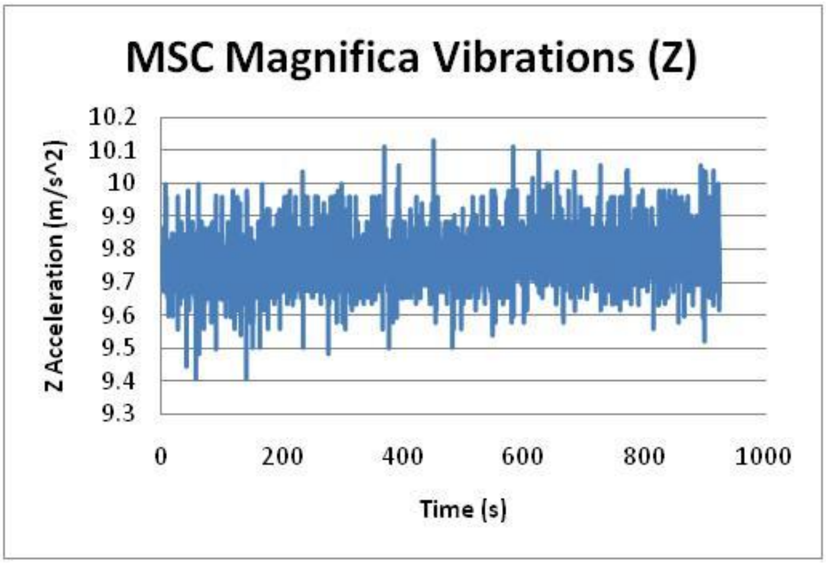

Figure 81: *MSC Magnifica* at Zattere (Z) (11-20-2010)

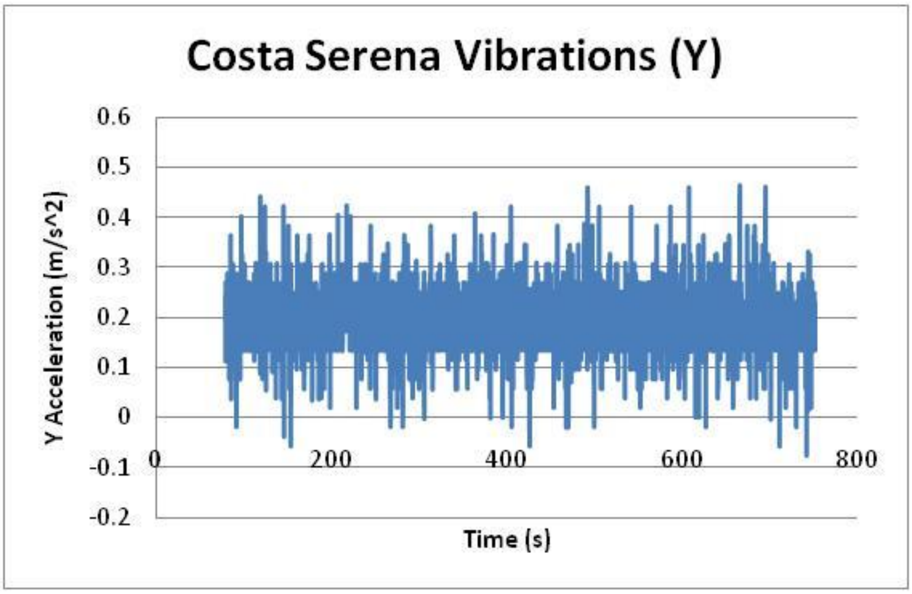

Figure 82: *Costa Serena* at San Basilio (Y) (11-21-2010)

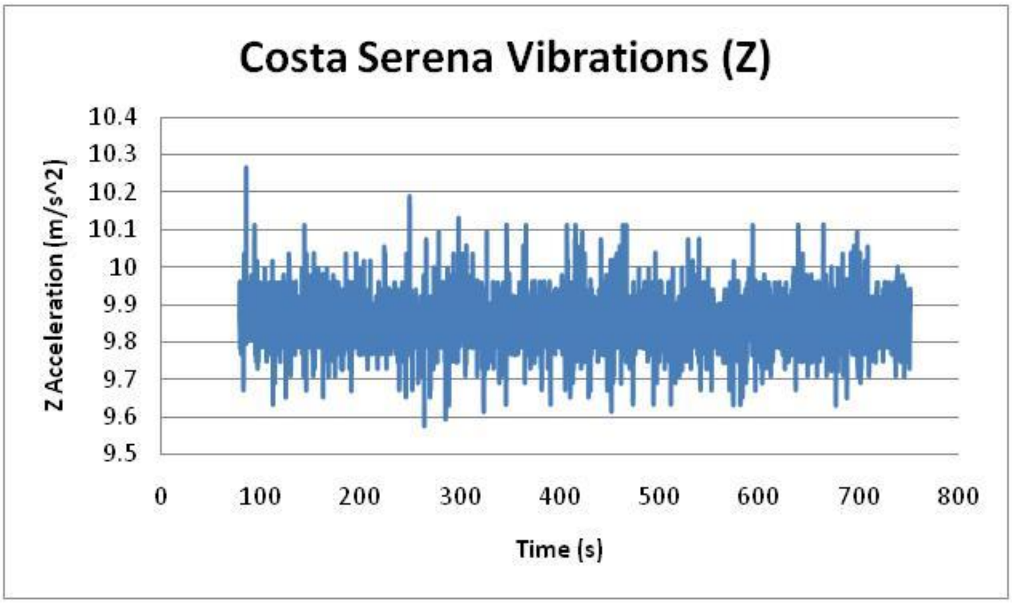

Figure 83: *Costa Serena* at San Basilio (Z) (11-21-2010)

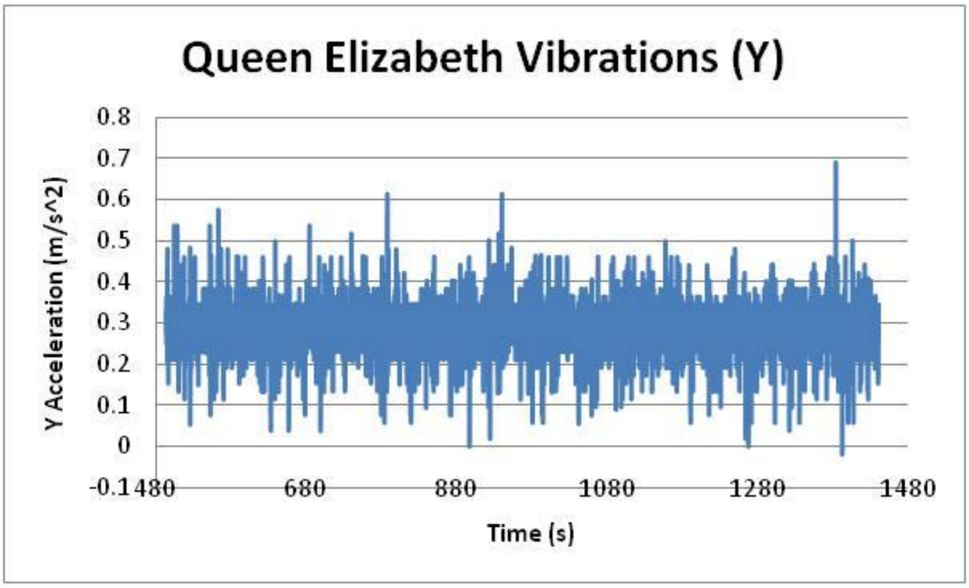

Figure 84: *Queen Elizabeth* at San Basilo (Y) (11-15-2010)

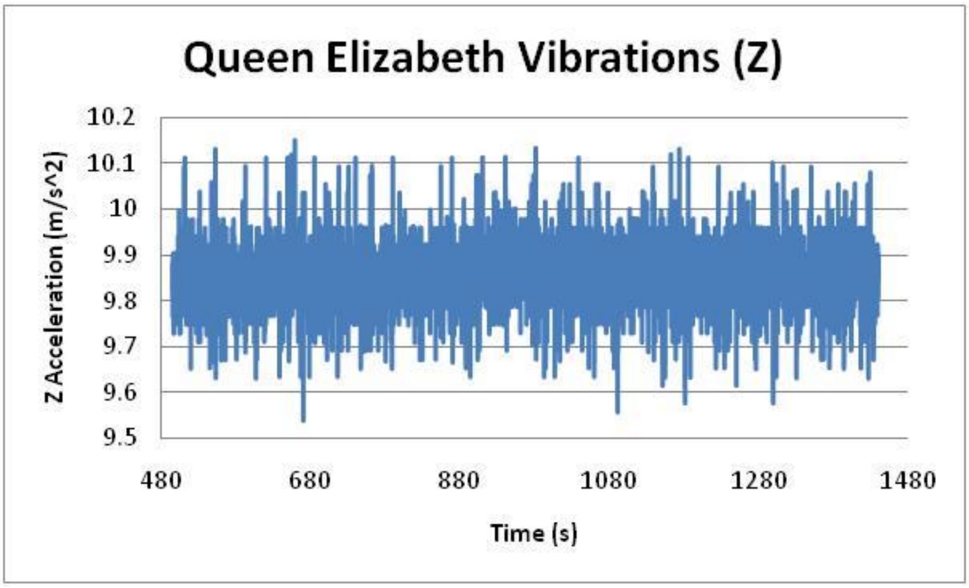

Figure 85: *Queen Elizabeth* at San Basilo (Z) (11-15-2010)

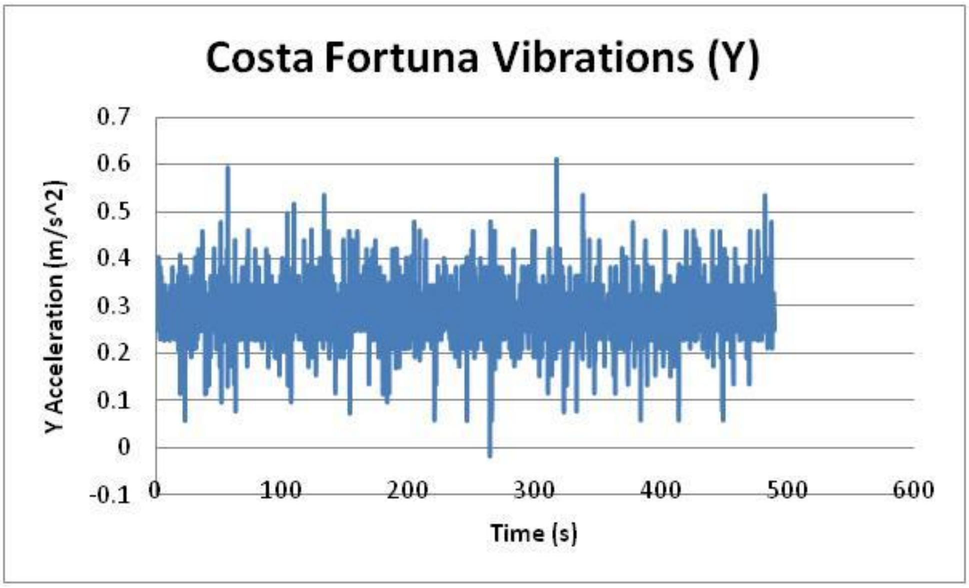

Figure 86: *Costa Fortuna* at San Basilio (Y) (11-15-2010)

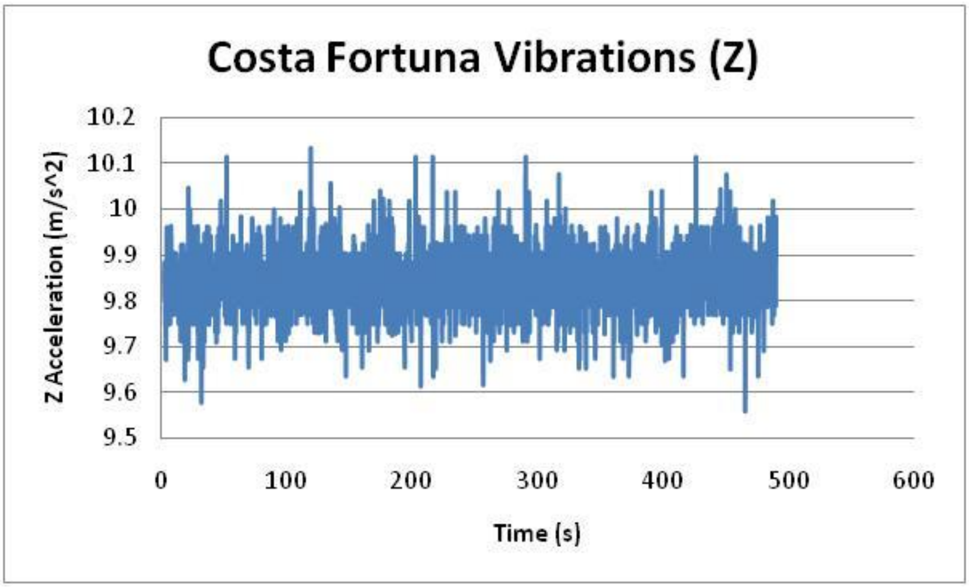

Figure 87: *Costa Fortuna* at San Basilio (Z) (11-15-2010)

Appendix F - Vibration Graph Minimums and Maximums

Table 10: Vibration Graph Minimums and Maximums

Ship	Direction	Time (s)	Minimum or Maximum	Cause
Costa Fortuna	X	34	Max	Ali
Costa Fortuna	X	107	Max	Boat
Costa Fortuna	X	164	Max	Ferry
Costa Fortuna	X	263	Max	Ship passing
Costa Fortuna	X	395	Max	Tugboat
Costa Fortuna	X	473	Max	coast guard boat
Costa Fortuna	X	85	Min	Boat
Costa Fortuna	X	135	Min	ACTV line
Costa Fortuna	X	381	Min	ACTV line and ship passing
Costa Fortuna	X	446	Min	ACTV line
Costa Fortuna	Y	57	Max	Ali
Costa Fortuna	Y	317	Max	ACTV line
Costa Fortuna	Y	23	Min	Ali
Costa Fortuna	Y	264	Min	Ship passing
Costa Fortuna	Z	51	Max	Ali
Costa Fortuna	Z	118	Max	Boat
Costa Fortuna	Z	202	Max	Ferry and ship
Costa Fortuna	Z	215	Max	Ship passing
Costa Fortuna	Z	290	Max	Ship passing
Costa Fortuna	Z	425	Max	ACTV
Costa Fortuna	Z	31	Min	Ali
Costa Fortuna	Z	206	Min	Ferry and ship
Costa Fortuna	Z	256	Min	ACTV line
Costa Fortuna	Z	465	Min	coast guard boat
Queen Elizabeth	X	518	Max	Nothing
Queen Elizabeth	X	544	Max	coast guard boat
Queen Elizabeth	X	689	Max	garbage boat
Queen Elizabeth	X	1098	Max	tugboat and taxi
Queen Elizabeth	X	1242	Max	garbage boat
Queen Elizabeth	X	1430	Max	?
Queen Elizabeth	X	617	Min	Nothing
Queen Elizabeth	X	638	Min	ship approaching
Queen Elizabeth	X	757	Min	garbage boat
Queen	X	860	Min	garbage boat

Elizabeth				
Queen Elizabeth	X	1128	Min	Boat
Queen Elizabeth	X	1251	Min	ACTV line
Queen Elizabeth	Y	788	Max	Ship passing
Queen Elizabeth	Y	940	Max	lone tugboat
Queen Elizabeth	Y	1384	Max	?
Queen Elizabeth	Y	897	Min	Ship passing
Queen Elizabeth	Y	1264	Min	ACTV line
Queen Elizabeth	Y	1393	Min	?

Appendix G - Hydrodynamic Measurements

Table 11: Velocity Measurements for *Star Princess*

Test 1											
Ship:	Star Princess			AVERAGE VELOCITY 30 MIN BEFORE PASSING:			0.52 m/s				
									% Increase:	65.2	
Tidal Condition:	3.5 hours after high tide			MAXIMUM VELOCITY:			0.78 m/s				
Wind:	Approx 10 mi/hr from South			MINIMUM VELOCITY:			0.51 m/s				
	FLOAT 1				FLOAT 2				FLOAT 3		
	Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)
	3	5.8	0.517241379		3	4.1	0.731707317		3	4.95	0.606060606
	6	5.6	0.535714286		6	4	0.75		6	5.1	0.588235294
	9	5.7	0.526315789		9	3.85	0.779220779		9	5.3	0.566037736
	12	5.5	0.545454545		12	3.95	0.759493671		12	5.55	0.540540541
	15	5.35	0.560747664		15	4.2	0.714285714		15	5.6	0.535714286
	18	5.05	0.594059406		18	4.3	0.697674419		18	5.8	0.517241379
	21	4.75	0.631578947		21	4.5	0.666666667		21	5.75	0.52173913
	24	4.4	0.681818182		24	4.8	0.625		24	5.9	0.508474576

Table 12: Velocity Measurements for *MSC Magnifica*

Test 2											
Ship:	MSC Magnifica			AVERAGE VELOCITY 30 MIN BEFORE PASSING:			0.50 m/s				
									% Increase:	38.7	
Tidal Condition:	1.5 hours after high tide			MAXIMUM VELOCITY:			0.68 m/s				
Wind:	Approx 15 mi/hr from South			MINIMUM VELOCITY:			0.49 m/s				
	FLOAT 1				FLOAT 2				FLOAT 3		
	Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)
	3	6.1	0.491803279		3	4.7	0.638297872		3	5.25	0.571428571
	6	6.15	0.487804878		6	4.4	0.681818182		6	5.3	0.566037736
	9	6	0.5		9	4.45	0.674157303		9	5.55	0.540540541
	12	5.9	0.508474576		12	4.5	0.666666667		12	5.7	0.526315789
	15	5.75	0.52173913		15	4.6	0.652173913		15	5.9	0.508474576
	18	5.4	0.555555556		18	4.8	0.625		18	6	0.5
	21	5.2	0.576923077		21	4.9	0.612244898		21	6	0.5
	24	4.9	0.612244898		24	5.05	0.594059406		24	6.05	0.495867769

Table 13: Velocity Measurements for *Costa Serena*

Test 3											
Ship:	Costa Serena			AVERAGE VELOCITY 30 MIN BEFORE PASSING:			0.52 m/s				
									% Increase:	45.1	
Tidal Condition:	2 hours after high tide			MAXIMUM VELOCITY:			0.73 m/s				
Wind:	Approx 5 mi/hr from East			MINIMUM VELOCITY:			0.50 m/s				
	FLOAT 1				FLOAT 2				FLOAT 3		
	Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)
	3	5.95	0.504201681		3	4.4	0.681818182		3	4.8	0.625
	6	5.8	0.517241379		6	4.2	0.714285714		6	5.15	0.582524272
	9	5.7	0.526315789		9	4.15	0.722891566		9	5.3	0.566037736
	12	5.45	0.550458716		12	4.2	0.714285714		12	5.5	0.545454545
	15	5.15	0.582524272		15	4.1	0.731707317		15	5.7	0.526315789
	18	5	0.6		18	4.2	0.714285714		18	5.85	0.512820513
	21	4.95	0.606060606		21	4.3	0.697674419		21	6.05	0.495867769
	24	4.6	0.652173913		24	4.55	0.659340659		24	6	0.5

Table 14: Velocity Measurements for *Splendour of the Seas*

Test 4											
Ship:	Splendour of the Seas			AVERAGE VELOCITY 30 MIN BEFORE PASSING:			0.48 m/s				
									% Increase:	66.8	
Tidal Condition:	2 hours before low tide			MAXIMUM VELOCITY:			0.79 m/s				
Wind:	Approx 5 mi/hr from East			MINIMUM VELOCITY:			0.47 m/s				
	FLOAT 1				FLOAT 2				FLOAT 3		
	Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)
	3	6.45	0.465116279		3	4.85	0.618556701		3	4.4	0.681818182
	6	6.3	0.476190476		6	4.5	0.666666667		6	4.65	0.64516129
	9	6.3	0.476190476		9	4.35	0.689655172		9	4.9	0.612244898
	12	6.05	0.495867769		12	4.1	0.731707317		12	5.15	0.582524272
	15	5.8	0.517241379		15	3.9	0.769230769		15	5.3	0.566037736
	18	5.5	0.545454545		18	3.8	0.789473684		18	5.6	0.535714286
	21	5.15	0.582524272		21	3.95	0.759493671		21	5.8	0.517241379
	24	5.2	0.576923077		24	4.3	0.697674419		24	5.95	0.504201681

Table 15: Velocity Measurements for *Norwegian Gem*

Test 5											
Ship:	Norwegian Gem			AVERAGE VELOCITY 30 MIN BEFORE PASSING:			0.46 m/s				
									% Increase:	68.2	
Tidal Condition:	2 hours before low tide			MAXIMUM VELOCITY:			0.76 m/s				
Wind:	Approx 5 mi/hr from South			MINIMUM VELOCITY:			0.45 m/s				
	FLOAT 1				FLOAT 2				FLOAT 3		
	Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)		Distance(m)	Time(s)	Velocity(m/s)
	3	6.5	0.461538462		3	4.45	0.674157303		3	5	0.6
	6	6.65	0.45112782		6	4.1	0.731707317		6	5.25	0.571428571
	9	6.3	0.476190476		9	4	0.75		9	5.4	0.555555556
	12	6.05	0.495867769		12	3.95	0.759493671		12	5.7	0.526315789
	15	5.8	0.517241379		15	4.15	0.722891566		15	5.95	0.504201681
	18	5.5	0.545454545		18	4.3	0.697674419		18	6.2	0.483870968
	21	5.15	0.582524272		21	4.6	0.652173913		21	6.45	0.465116279
	24	4.8	0.625		24	4.85	0.618556701		24	6.6	0.454545455

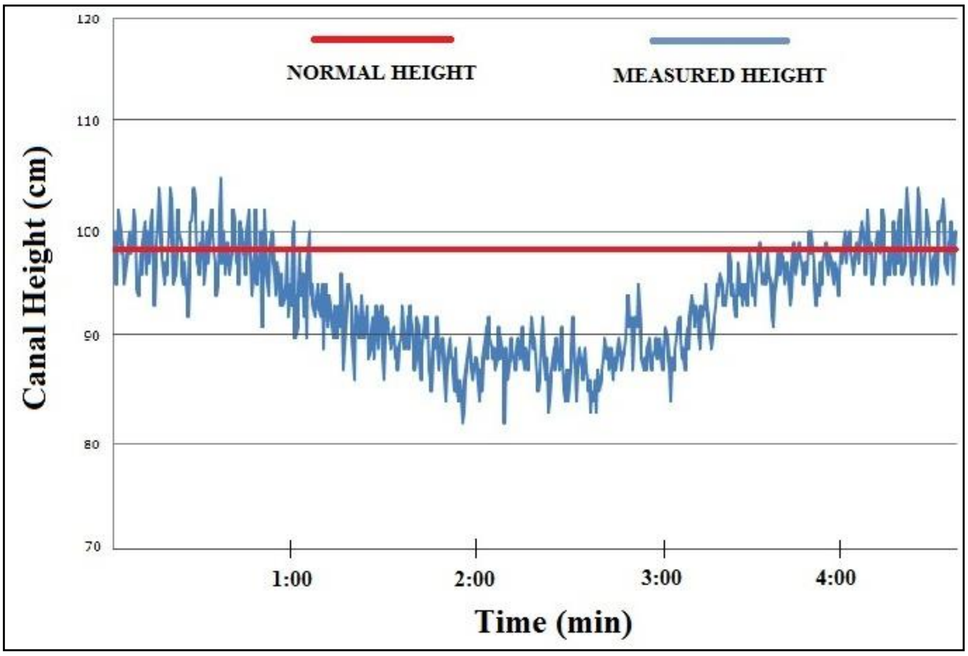

Figure 88: Canal Height Measurements for *MSC Magnifica*

COMUNE
DI VENEZIA

Centro Previsioni
e
Segnalazioni Maree

Consiglio Nazionale delle Ricerche
ISMAR - Istituto di Scienze Marine
Sezione di Ricerca di Venezia

Analisi degli effetti idrodinamici indotti nei rii di S.Basilio, S.Martin, Ponte Piccolo e S.Eufemia, in corrispondenza del passaggio delle grandi navi da crociera nel Canale della Giudecca e in Bacino di S.Marco

RELAZIONE DI SINTESI

Febbraio 2004

Franco Costa - Aleardo Zuliani

Consiglio Nazionale delle Ricerche
ISMAR – Istituto di Scienze Marine
Sezione di Ricerca di Venezia – Studio dei Sistemi Marini e Costieri
S.Polo, 1364 – 30125 Venezia
tel. 041/5216816 – fax. 041/5216815
franco.costa@ismar.cnr.it -- aleardo.zuliani@ismar.cnr.it

L'attività descritta nella Relazione è stata svolta su incarico del Comune di Venezia – Centro Previsioni e Segnalazioni Maree (Determinazioni n. 1979 del 13.8.2003 e n. 3035 del 12.12.2003)

Figure 89: CNR - ISMAR Study Cover Page

Appendix H - Using the Aethalometer

Figure 90: Charging the Aethalometer

Figure 91: Changing the Aethalometer's Filter

Figure 92: Obtaining data from Aethalomter

Figure 93: Placement of Aethalometer in the Harbor (3)

Figure 94: Placement of Aethalometer in the Harbor (4)

Figure 95: Air Pollution from a Cruise Ship (2)

Figure 96: Air Pollution from a Ferry

Appendix I - BC Data

Table 16: Example Chart of Aethalometer Data

		BC Data Analysis Sheet		
		Venice, Italy - Harbor	Chart Title:	Micro Aethalometer Data : Venice, Italy - Harbor
	Serial Number:	S2-338	Chart Date:	19-Nov-10
	Smoothing Parameter:	1	Chart Day:	Friday 19-Nov-10
	No. of Wavelengths:	1	s/n ID :	Micro Aethalometer Serial No. S2-338
		Smoothed data	Avge 3 raw	Dev. Raw-Avg.
Time	BC	BC		263
17:38:00	-47	-47		
17:39:00	1021	768		
17:40:00	1331	1364	1364	33
17:41:00	1740	1766	1766	26
17:42:00	2226	2028	2028	198
17:43:00	2118	2195	2195	77

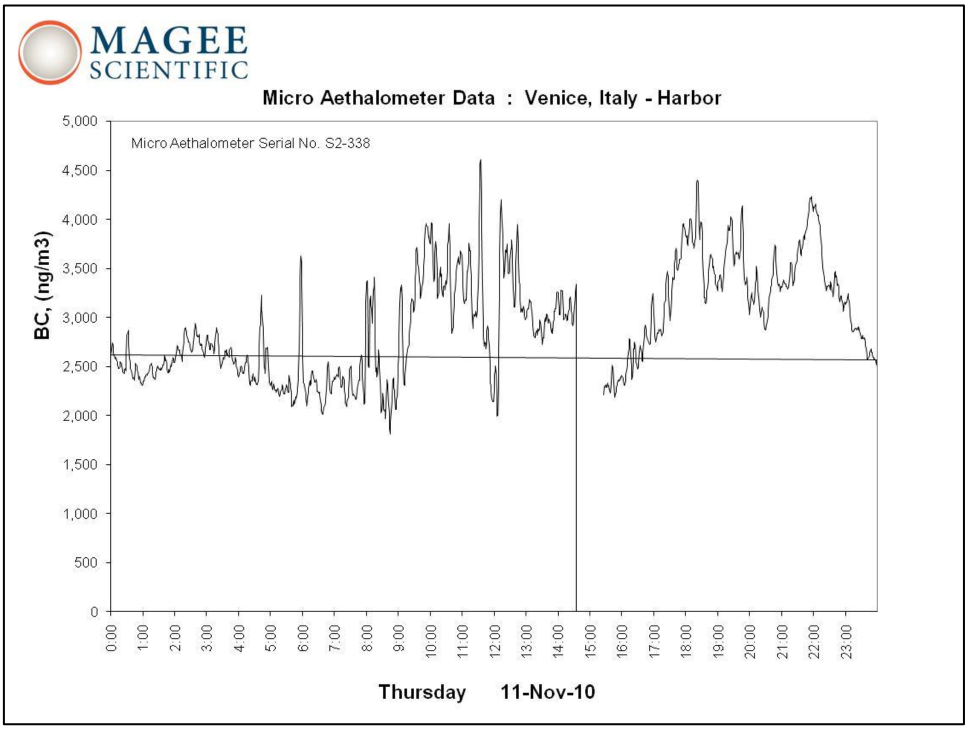

Figure 97: BC Data – 11/11/10 to 11/12/10

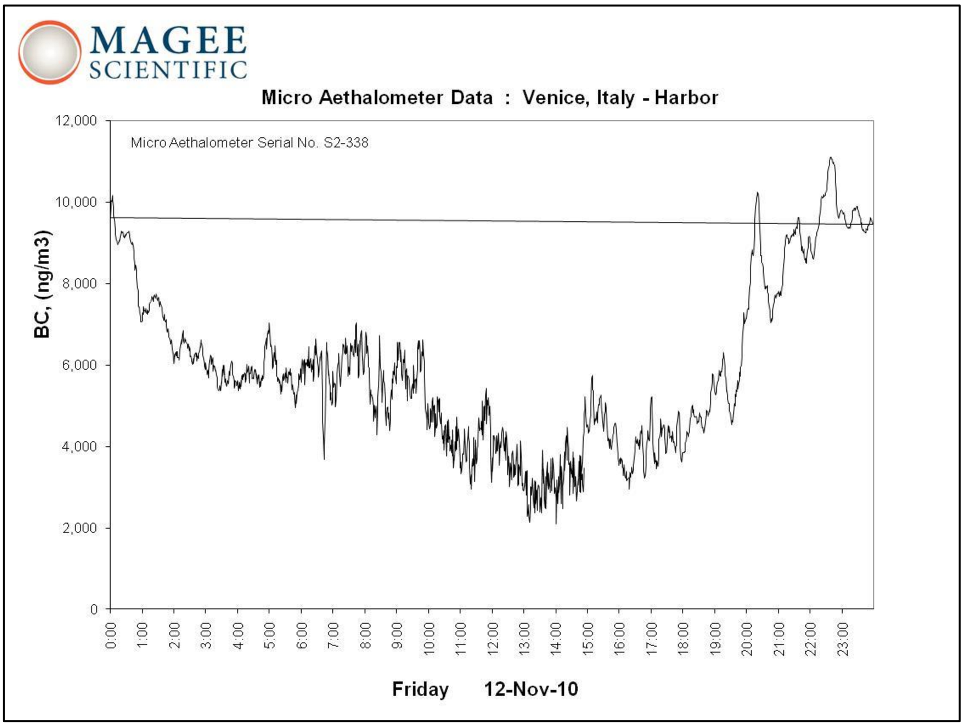

Figure 98: BC Data – 11/12/10 to 11/13/10

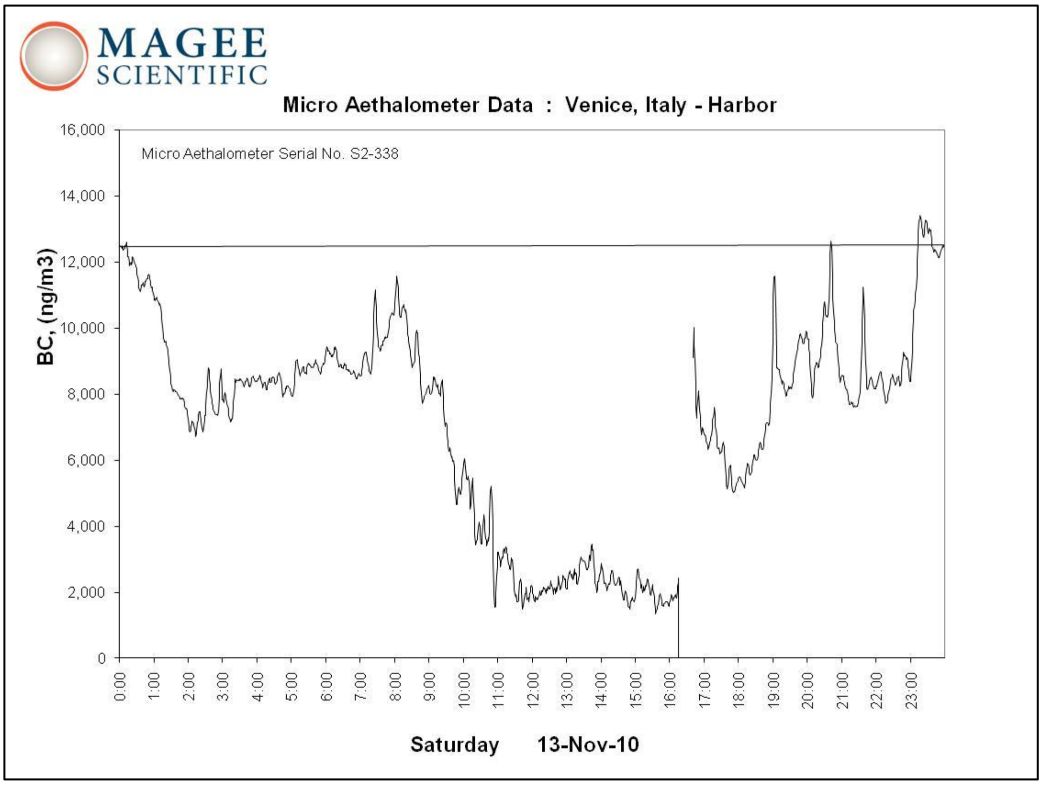

Figure 99: BC Data – 11/13/10 to 11/14/10

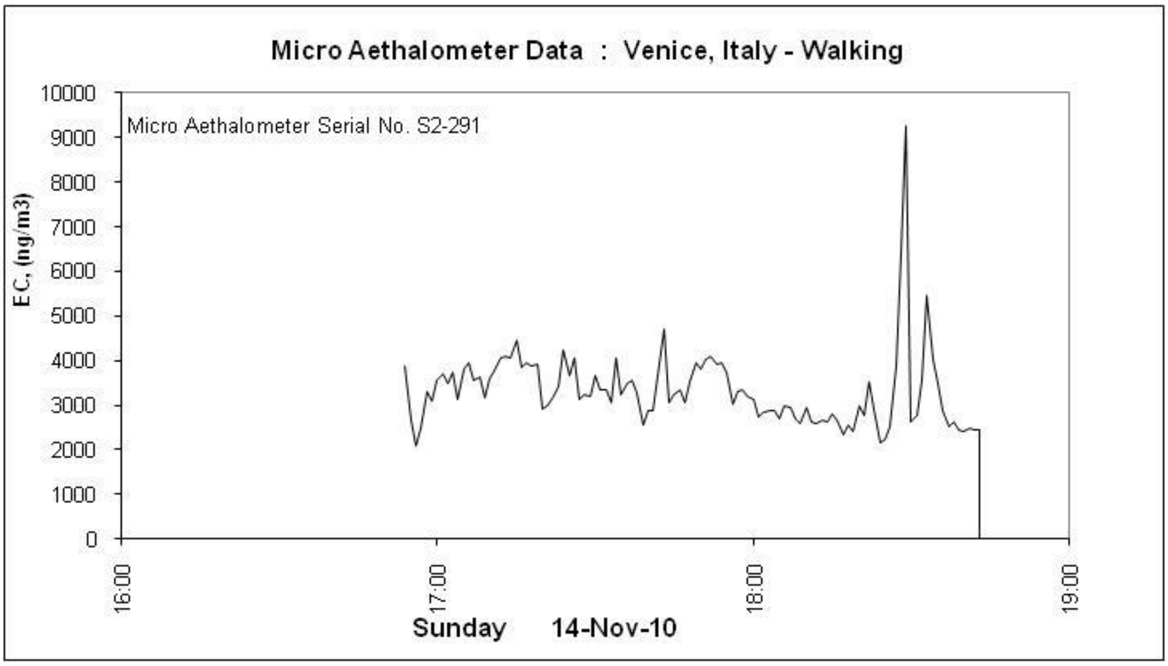

Figure 100: BC Data - Walking (2)

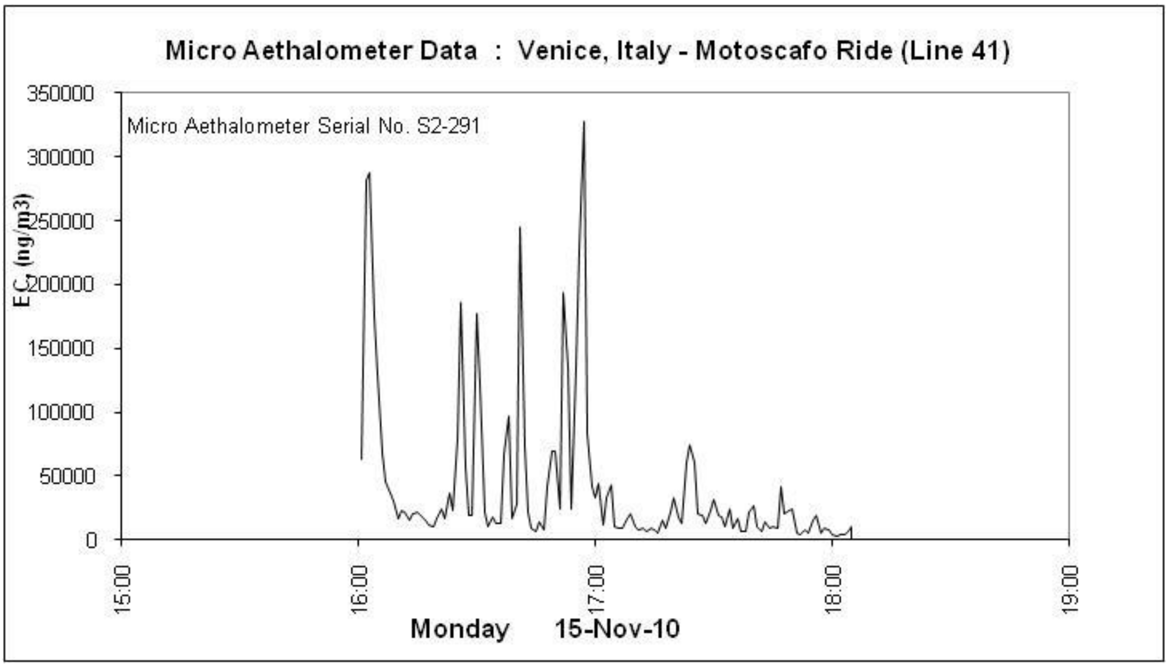

Figure 101: BC Data for Motoscafo Ride (2)

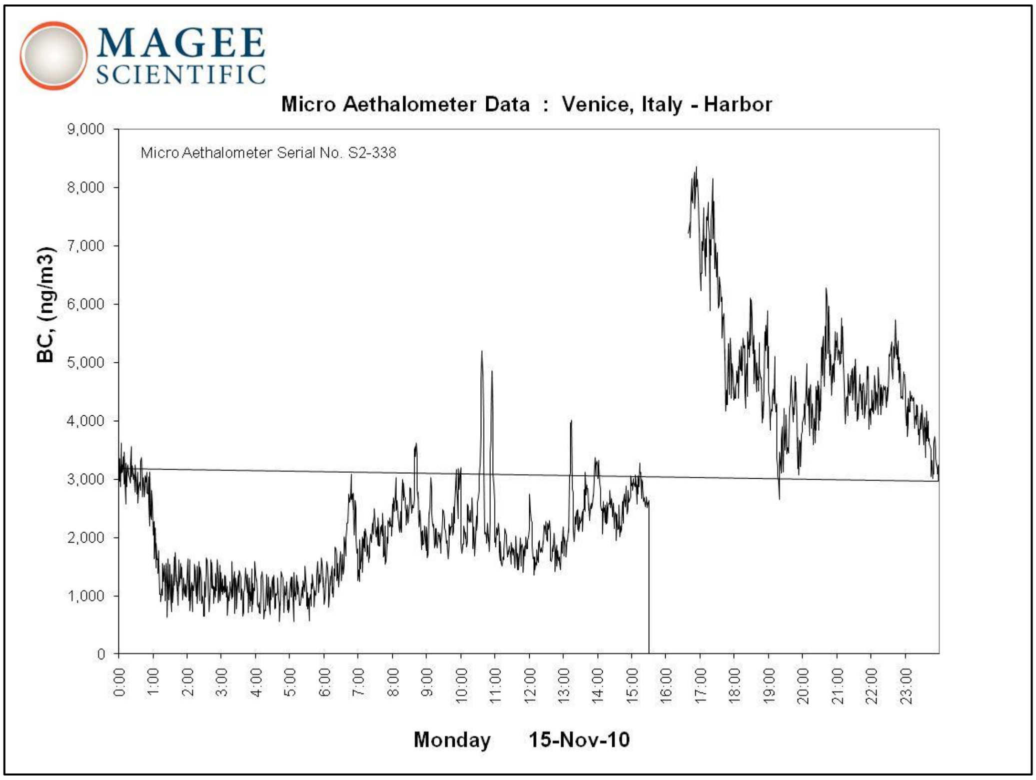

Figure 102: BC Data – 11/15/10 to 11/16/10

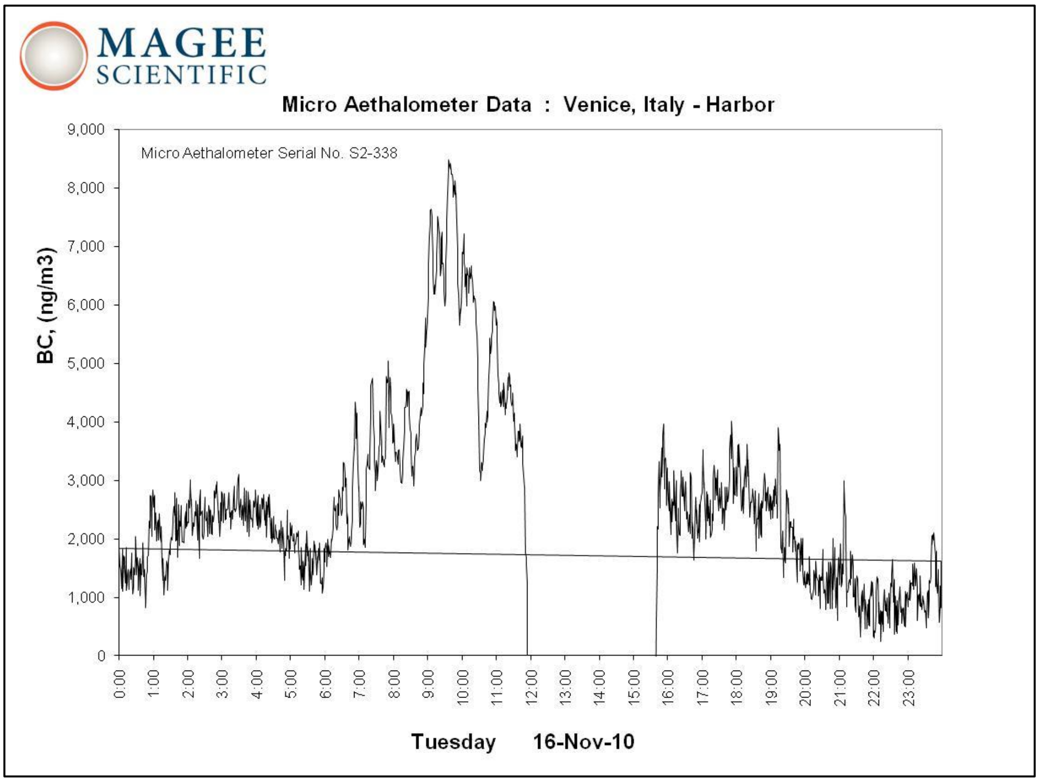

Figure 103: BC Data – 11/16/10 to 11/17/10

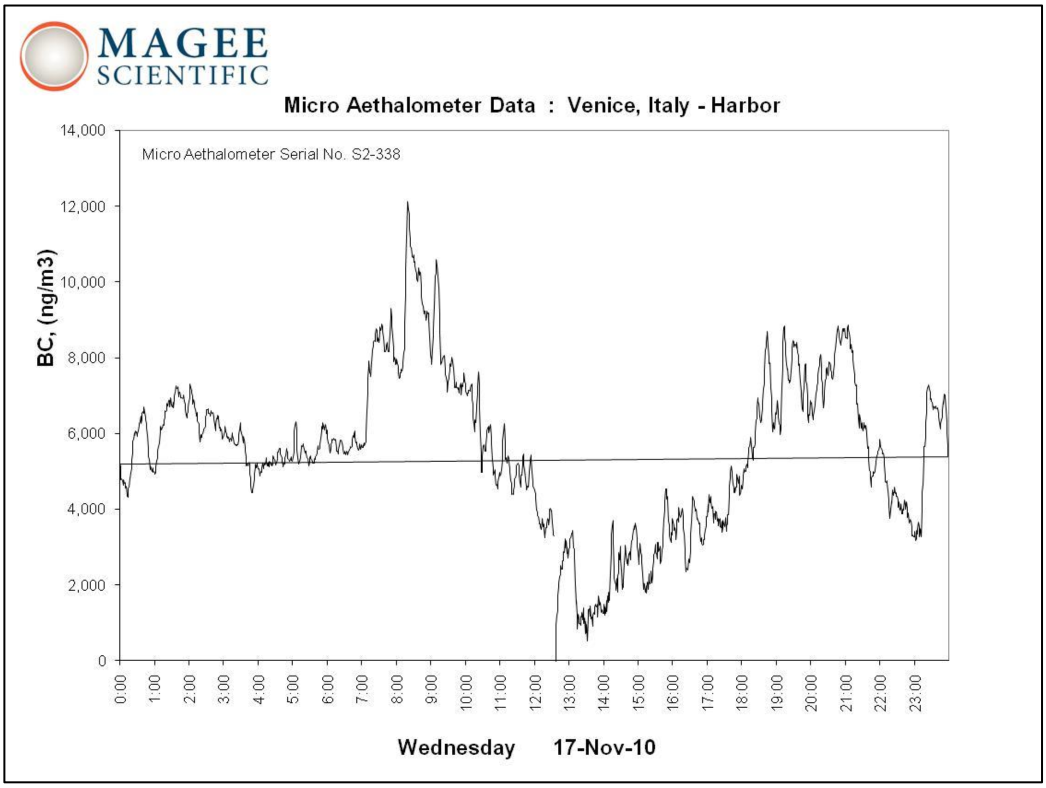

Figure 104: BC Data – 11/17/10 to 11/18/10

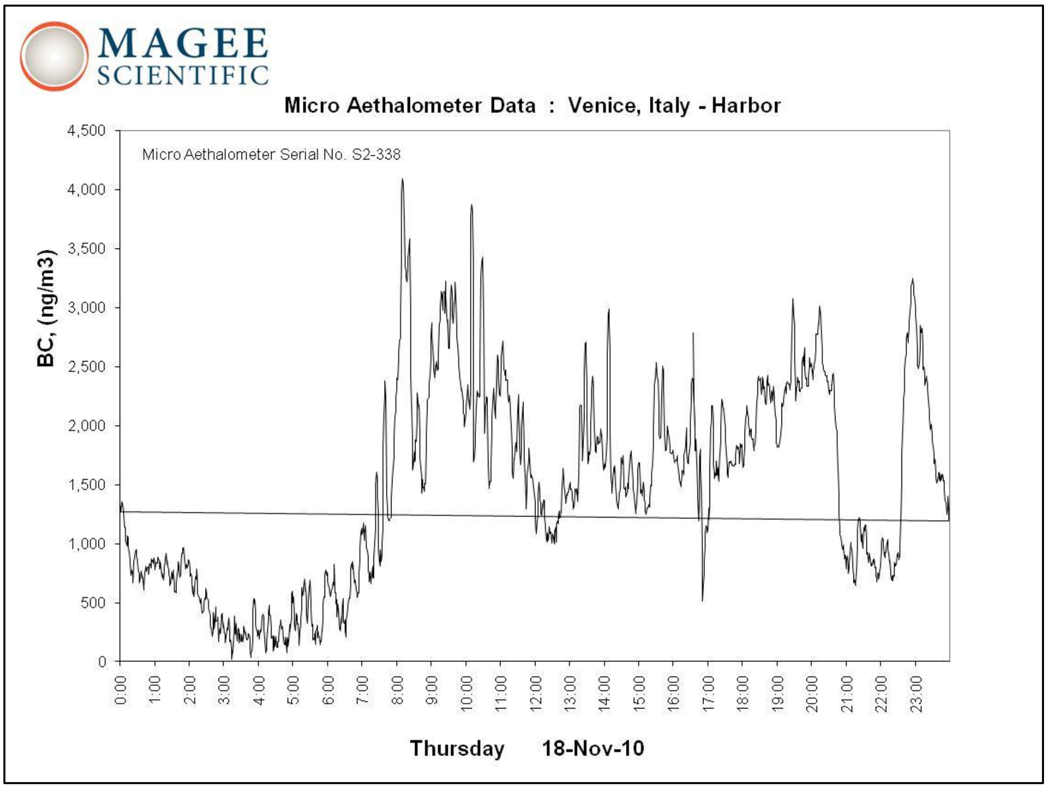

Figure 105: BC Data – 11/18/10 to 11/19/10

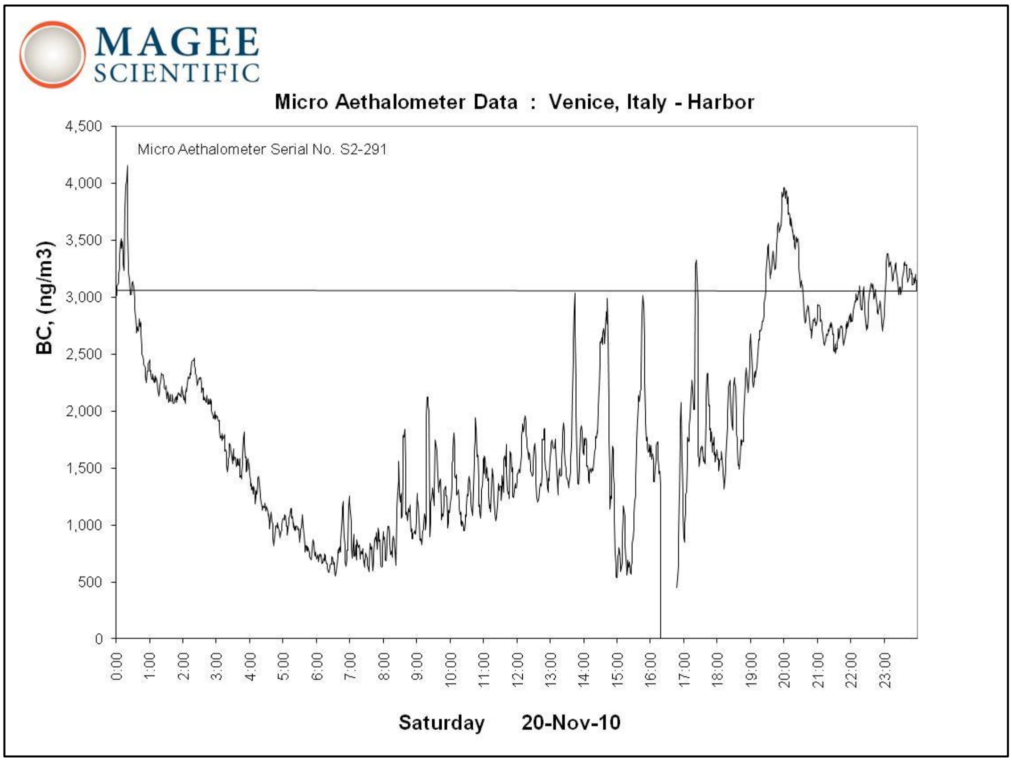

Figure 106: BC Data – 11/20/10 to 11/21/10

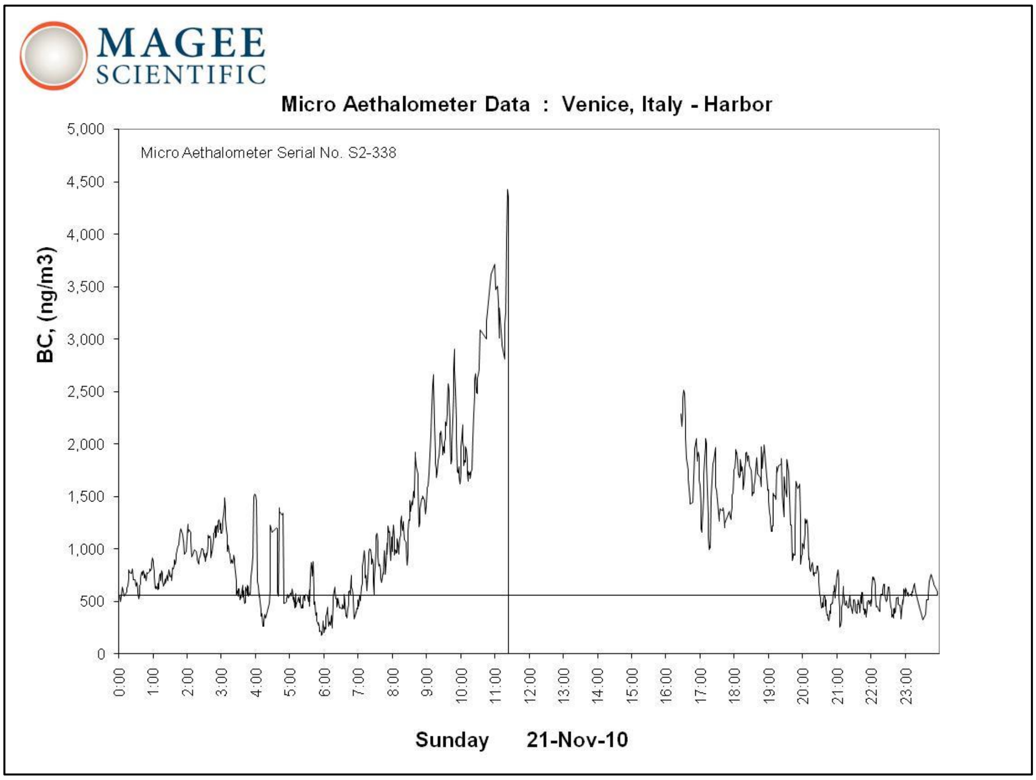

Figure 107: BC Data – 11/21/10 to 11/22/10

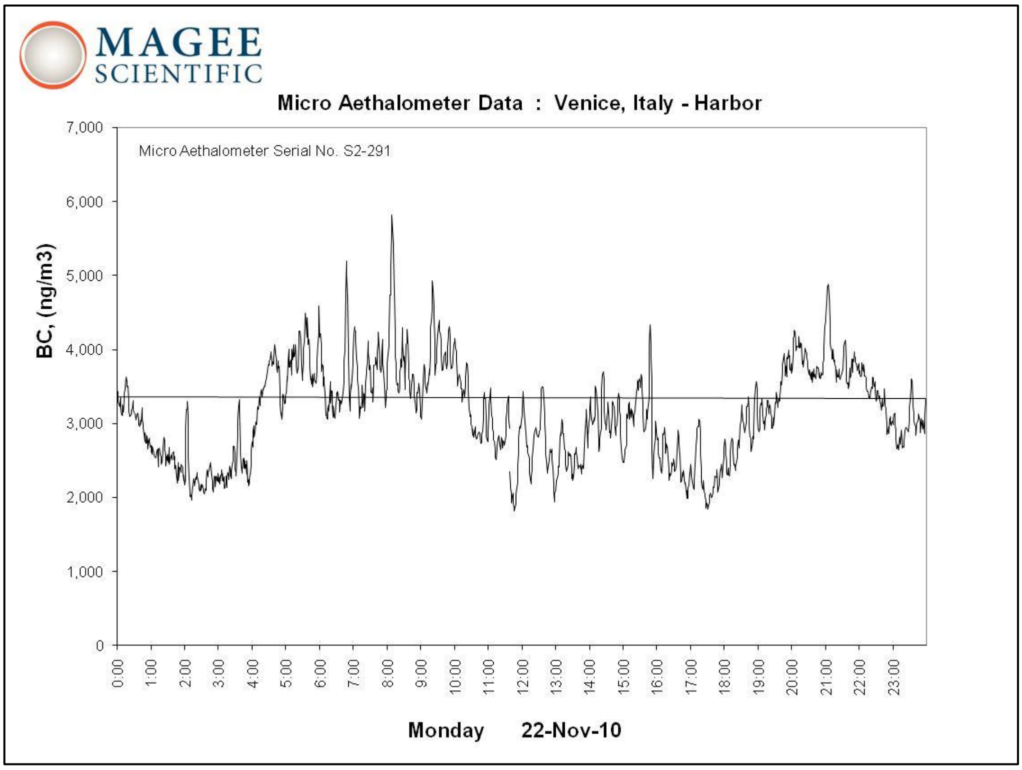

Figure 108: BC Data – 11/22/10 to 11/23/10

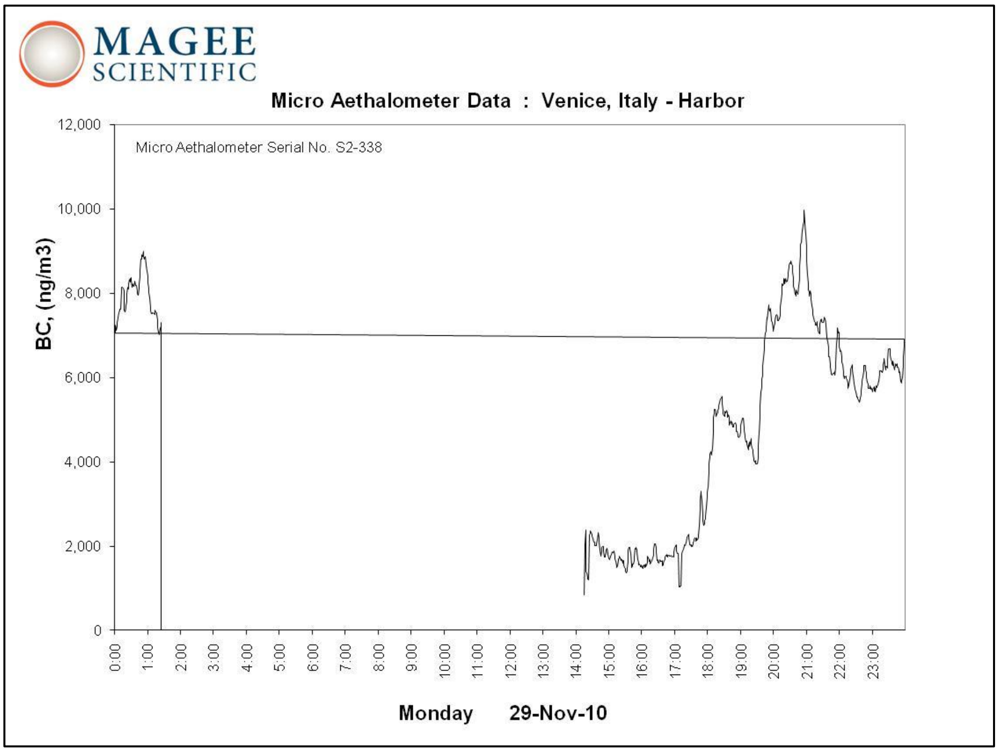

Figure 109: BC Data – 11/29/10 to 11/30/10

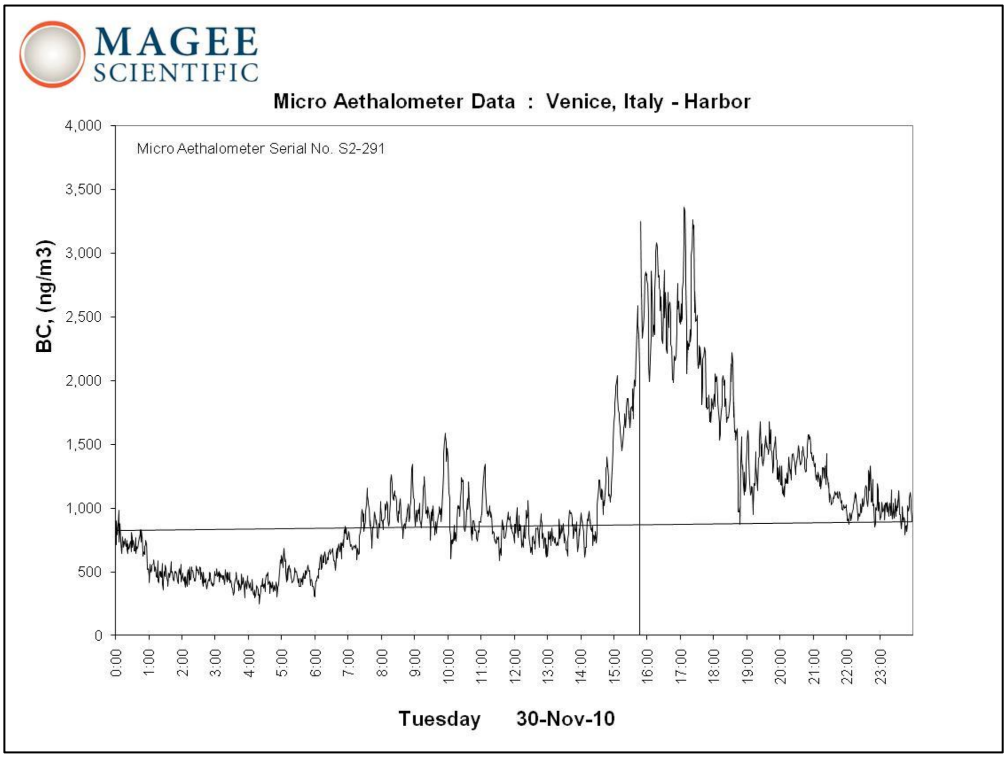

Figure 110: BC Data – 11/30/10 to 12/1/10

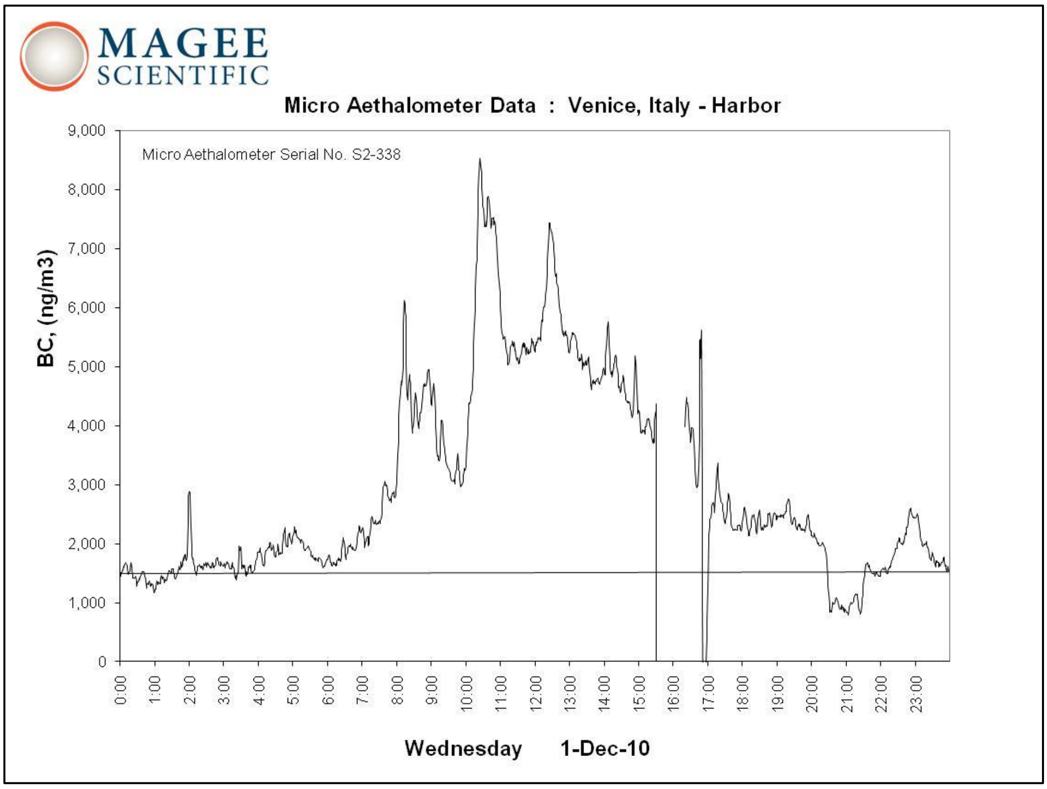

Figure 111: BC Data – 12/1/10 to 12/2/10

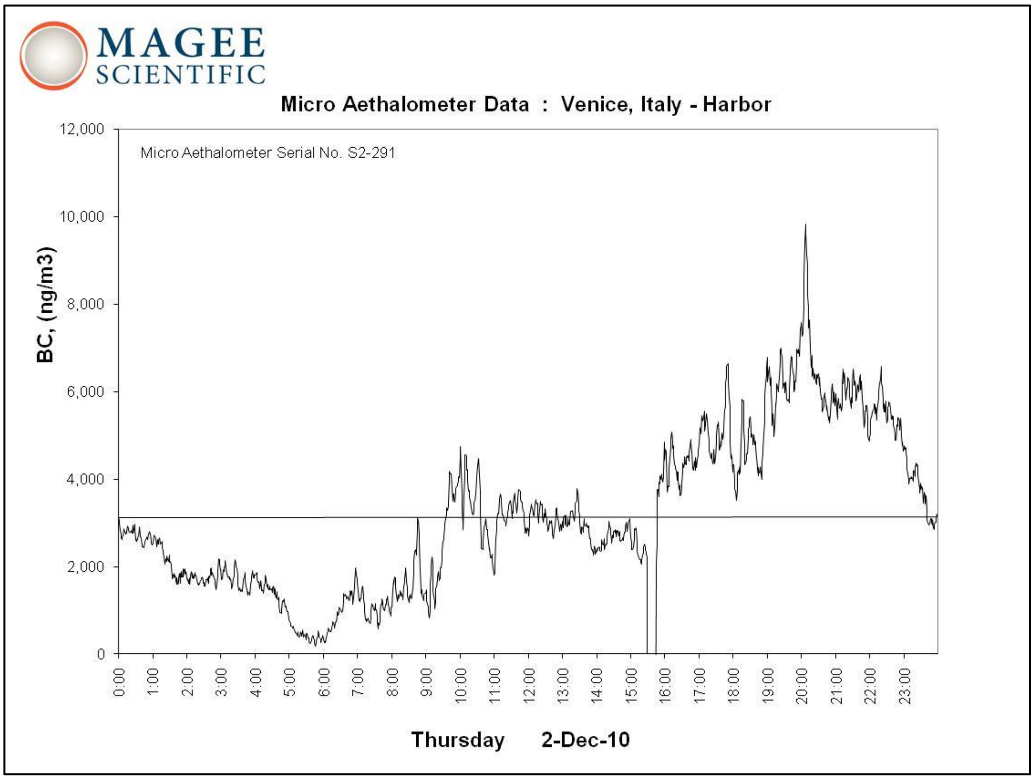

Figure 112: BC Data – 12/2/10 to 12/3/10

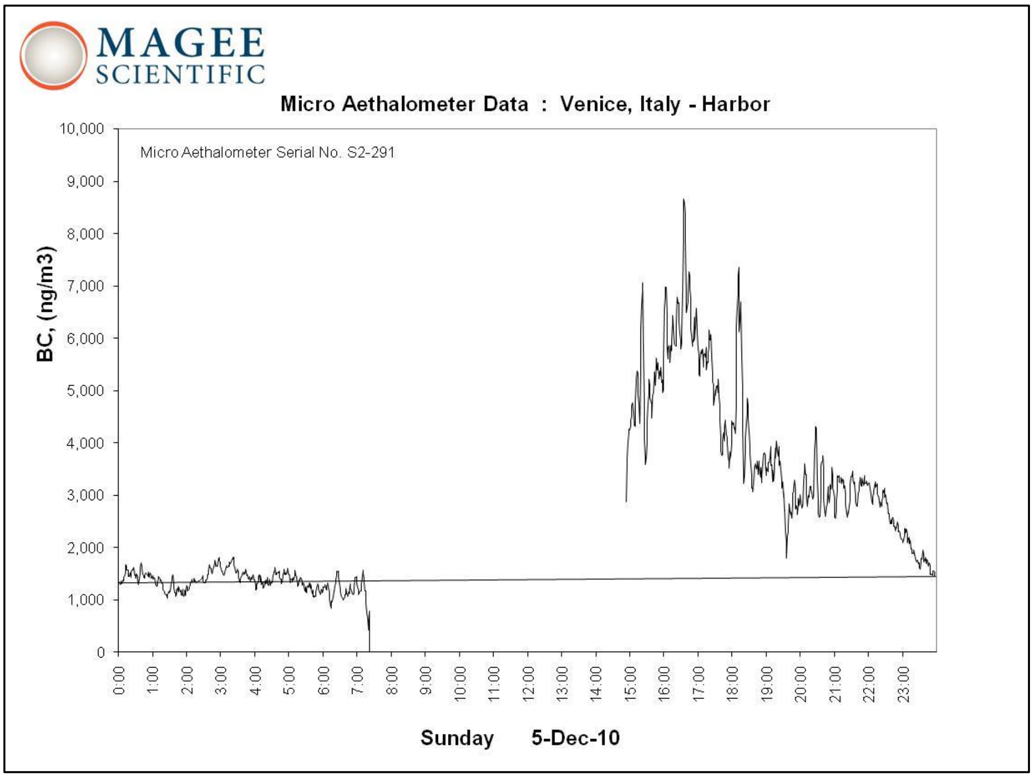

Figure 113: BC Data – 12/5/10 to 12/6/10

Appendix J - Boat Choices

Table 17: Boat Choices 11/6/10

	Taxis		Ali Laguna		Other Boats		
Time:7:58	People	#of Taxis	People	Boat	People	Boat	Type
8:13	9	3	8	1	0	0	
8:28	11	5	0	0	0	0	
8:43	22	9	40	1	0	0	
8:58	67	21	0	0	14	2	Blue(Line)
9:13	82	23	54	1	30	1	Venezia motoscafi
9:28	54	18	0	0	0	0	
9:43	33	10	129	1	0	0	
9:58	60	13	50	1	117	1	Ducalevenezia
10:13	22	3	107	1	0	0	
10:28	7	2	57	1	12	1	Yellow(line)
10:43	6	2	100	1	0	0	
10:58	7	2	49	1	0	0	
Total	380	111	594	9	173	5	

Table 18: Boat Choices

	Alilaguna	**Vaporetti/Middle Dock**	**Water taxis**	**Total**
31-Oct	561	220	468	1249
6-Nov	594	173	380	1147
10-Nov	126	365	233	724
	1281	**758**	**1081**	3120

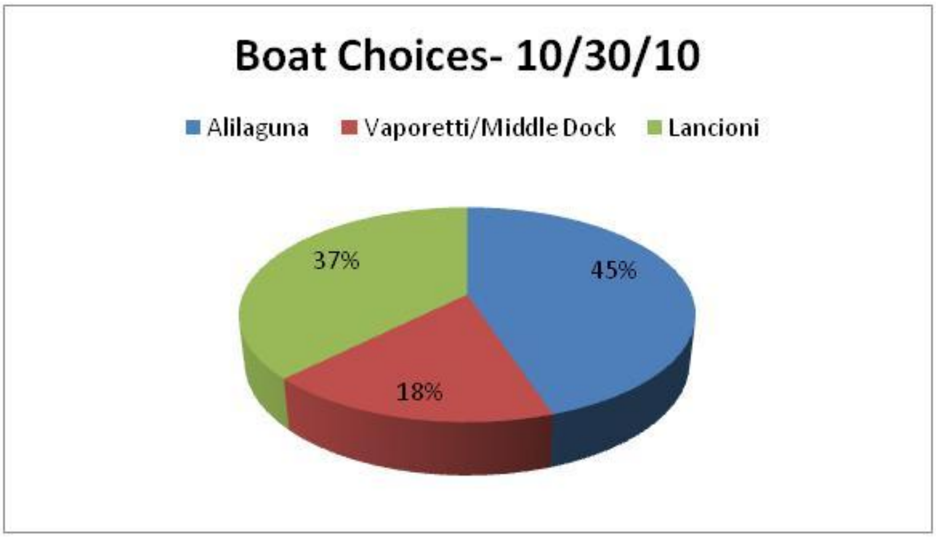

Figure 114: Boat Choices - 10/30/10

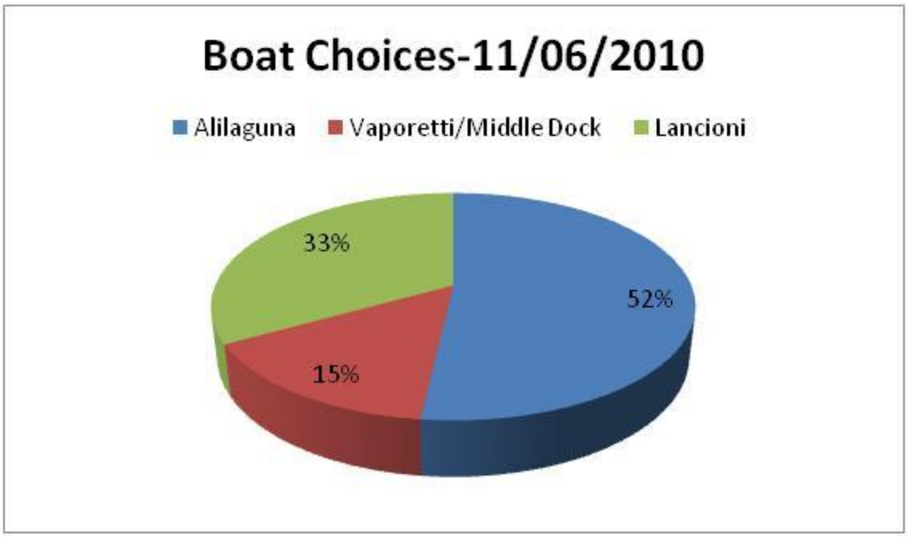

Figure 115: Boat Choices - 11/6/10

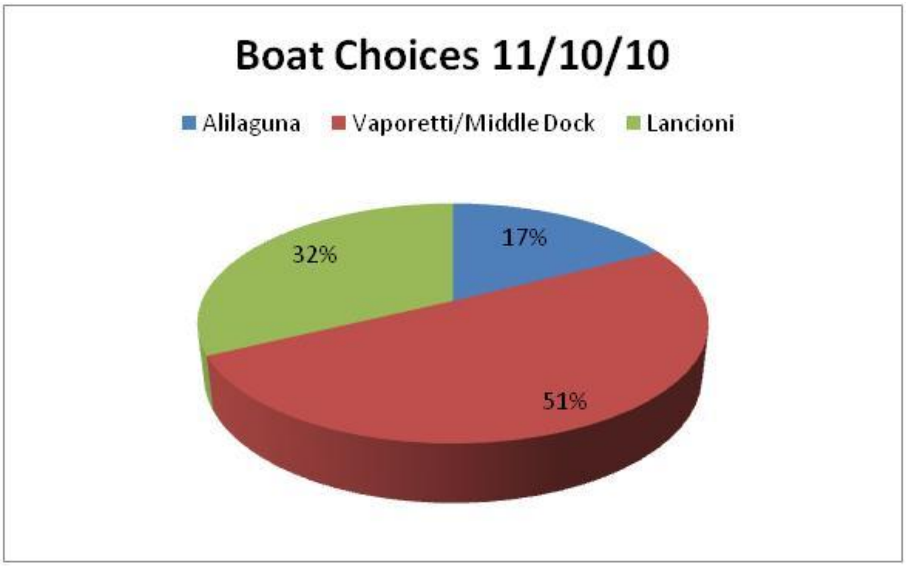

Figure 116: Boat Choices - 11/10/10

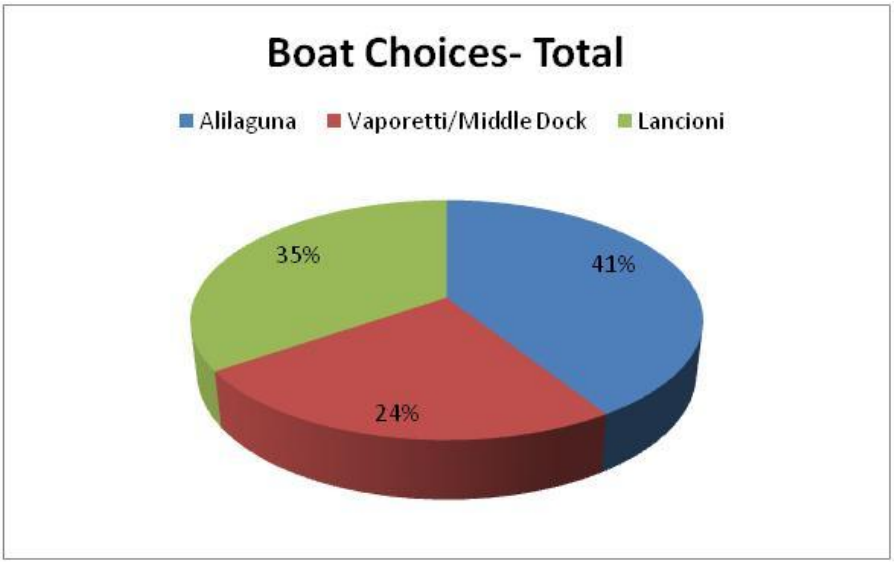

Figure 117: Boat Choices - Total

Appendix K - Contacts

Contacts

Venice IQP B10 Ships

Venice

- **Jeff Blair**: (jeff.blair@mageescientific.com); CEO of Magee Scientific and former VPC student. Contact to obtain aethalometer(s). Also contact Grisa Mocnik (Grisa.Mocnik@aerosol.si); works with Jeff at the Slovenia location.
    - Tel: +1 (510) 845-2801 ext. 201 – Jeff
    - Mobile: +1 (510) 396-5189- Jeff
    - Tel: (+39) 386 59 191 220 - Grisa

Antonio Campagnol: (CPvenezia456@yahoo.it); Harbor Master, CF (CAPITANERIA DI PORTO). Contact for background information on cruise ships. Knows M. Zanforlin.

- Tel: (+39) 041 5334617-0
- Mobile: (+39) 329 421 99 21 or 329 0090910

- **Franco Fiorin**: (franco.fiorin@comune.venezia.it); Director of Transportation of the Venice Mobility Department; wasn't able to make contact with.
- **Alberto Gallo**: (gallo@formaurbis.com); Prof Carrera's brother-in-law; good connection to obtain Venetian contacts; works at the VPC.
    - VPC Office: (+39) 041-523-3209
    - Mobile: (+39) 335-623-9391

Alfonso Morisieri: (resmaritima@mac.com); for navigation regulations/issues.

Marco Nogara: (venexmaster1@libero.it); Cruise Ship Captain for Disney Cruise Line. Contact for background information on cruise ships/industry.

- Mobile: (+39) 340 5006144

Roberto Spinazze: (rspinazze@arpa.veneto.it); ARPAV (European version of the EPA for Venice). Works with Dr. Enzo Tarabotti (etarabotti@arpa.veneto.it) and Luisa Vianello (lvianello@arpa.veneto.it). Possible future collaboration with measuring particulate emissions (BC) w/ VTP and Magee Scientific.

- Tel: (+39) 0415445640

Luca Zaggia: (l.zaggia@ve.ismar.cnr.it); Istituto di Scienze Marine (ISMAR). Contact for hydrodynamic information.

- Tel: (+39) 041 2404785

Marco Zanforlin: (m.zanforlin@vtp.it); Venezia Terminal Passeggeri (VTP); R.S.P.P. – Safety Dept. / P.F.S.O./A.Q.; Safety/Security/Quality Manager. Contact for access to the Marittima (harbor) and information on cruise ships/industry; works with colleagues Jacopo, Riccardo and Karin, who assisted us in the harbor.

- Tel: (+39) 041 2403035
- Mobile 1: (+39) 334 6085591
- Mobile 2: (+39) 335 7272728

WPI

- **Professor David Olinger:** (olinger@wpi.edu); Mechanical Engineering Professor
    - Tel: (+1) 508-831-5698

Shane Bellingham
Cortney Davis
Christopher O'Brien
Erin Saari
Interdisciplinary and Global Studies Division
100 Institute Road
Worcester, MA 01609
ve10-ships@wpi.edu

Mr. Jeff Blair, CEO
Magee Scientific Corporation
1101 Cowper Street
Berkeley, CA 94702
Jeff.Blair@mageescientific.com

September 1, 2010

Mr. Blair,

Beginning last year engineering students from Worcester Polytechnic Institute (WPI) have studied the comprehensive effects of cruise ships on the historic city of Venice. This year, our project team consists of four third-year students here at WPI: Shane Bellingham, Cortney Davis, Christopher O'Brien, and Erin Saari. One of our principle objectives will be to quantitatively assess the carbon emissions from docked cruise ships. After being informed of your extensive background and experience pertaining to air quality and emission monitoring, we would be delighted with the prospect of your future cooperation.

Over the course of the next few months, we plan to research the context of this issue and further establish the objectives that our project should satisfy. We also plan to develop a methodology for implementing the project, culminating in a project proposal that we shall then use as a basis for the actual project in Venice. We request that you grant us permission to contact you during this preparation period for any clarifications that we may need. More specifically, if you could inform us as to your preferred time and number at which to conduct phone correspondence. Finally, if you have or are aware of any materials that you believe will assist the project planning process, we would greatly appreciate it if you could direct us to these sources.

Thank you in advance for any assistance you can offer our group. Any information would surely prove instrumental in our efforts. Project updates will be periodically posted on: sites.google.com/site/ve10-ships/. We would greatly appreciate if you would confirm receipt of this letter via email to ve10-ships@wpi.edu, and sincerely look forward to hearing from you soon.

Warm regards,

Shane Bellingham, Mechanical Engineering

Cortney Davis, Biology and Pre-Medicine

Christopher O'Brien, Mechanical Engineering

Erin Saari, Chemical Engineering

Shane Bellingham
Cortney Davis
Christopher O'Brien
Erin Saari
Interdisciplinary and Global Studies Division
100 Institute Road
Worcester, MA 01609
ve10-ships@wpi.edu

Mr. Marco Zanforlin
Venezia Terminal Passeggeri
Marittima Fabbricato 248
Venezia, Italia
m.zanforlin@vtp.it

September 17, 2010

Mr. Zanforlin,

Beginning last year engineering students from Worcester Polytechnic Institute (WPI) have studied the comprehensive effects of cruise ships on the historic city of Venice. This year, our project team consists of four third-year students here at WPI: Shane Bellingham, Cortney Davis, Christopher O'Brien, and Erin Saari. One of our principle objectives is to quantitatively assess the dispersal of pedestrians disembarking their cruise liners. After being informed of your extensive background and experience pertaining to mobility within Venice, we would be delighted with the prospect of your future cooperation.

Over the course of the next few months, we plan to research the context of this issue and further establish the objectives that our project should satisfy. We also plan to develop a methodology for implementing the project, culminating in a project proposal that we shall then use as a basis for the actual project in Venice. We request that you grant us permission to contact you during this preparation period for any clarifications that we may need. More specifically, if you could inform us as to your preferred time and number at which to conduct phone correspondence. Finally, if you have or are aware of any materials that you believe will assist the project planning process, we would greatly appreciate it if you could direct us to these sources.

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Warm regards,

Shane Bellingham, Mechanical Engineering

Cortney Davis, Biology and Pre-Medicine

Christopher O'Brien, Mechanical Engineering

Erin Saari, Chemical Engineering

Shane Bellingham
Cortney Davis
Christopher O'Brien
Erin Saari
Interdisciplinary and Global Studies Division
100 Institute Road
Worcester, MA 01609
ve10-ships@wpi.edu

Mr. Antonio Campagnol
Harbor Master
Venice, Italy
cpvenezia456@yahoo.it

September 17, 2010

Mr. Campagnol,

Beginning last year engineering students from Worcester Polytechnic Institute (WPI) have studied the comprehensive effects of cruise ships on the historic city of Venice. This year, our project team consists of four third-year students here at WPI: Shane Bellingham, Cortney Davis, Christopher O'Brien, and Erin Saari. After being informed of your extensive background and experience pertaining to the dynamics and operations of the harbor, we would be delighted with the prospect of your future cooperation.

Over the course of the next few months, we plan to research the context of this issue and further establish the objectives that our project should satisfy. We also plan to develop a methodology for implementing the project, culminating in a project proposal that we shall then use as a basis for the actual project in Venice. We request that you grant us permission to contact you during this preparation period for any clarifications that we may need. More specifically, if you could inform us as to your preferred time and number at which to conduct phone correspondence. Finally, if you have or are aware of any materials that you believe will assist the project planning process, we would greatly appreciate it if you could direct us to these sources.

Thank you in advance for any assistance you can offer our group. Any information would surely prove instrumental in our efforts. Project updates will be periodically posted on: sites.google.com/site/ve10-ships/. We would greatly appreciate if you would confirm receipt of this letter via email to ve10-ships@wpi.edu, and sincerely look forward to hearing from you soon.

Warm regards,

Shane Bellingham, Mechanical Engineering

Cortney Davis, Biology and Pre-Medicine

Christopher O'Brien, Mechanical Engineering

Erin Saari, Chemical Engineering

TO: Marco Zanforlin

FROM: WPI Students: Shane Bellingham, Cortney Davis, Chris O’Brien and Erin Saari

DATE: October 27, 2010

RE: Measuring Particulate Emissions in the Marittima

The purpose of this memorandum is to inform you on our plans to measure the particulate emissions produced by cruise ships in Venice’s harbor (Marittima). To accomplish this objective we will be using an instrument known as an “aethalometer.” The device measures the black carbon emissions present in the atmosphere. The instrument uses an optical filtration system which collects the carbon content in the surrounding air in real time. Magee Scientific will be supplying the unit we intend to use in the harbor. The device is capable of measuring PM2.5 and PM10, depending on the instrument’s specific attachment/filter.

We intend to place this device somewhere in the vicinity of the Marittima. The location needs to be easily accessible on a daily basis and must be kept in a safe place, since the devices are very expensive (at least €4.300,00). The filters must be changed daily and will be processed by Magee Scientific.

Our fundamental objective is to measure the black carbon emissions produced by the cruise ships. In placing the aethalometer in the harbor, we will gain a better understanding of the emissions when compared to their schedules and the emissions produced by the other boats around Venice. We intend to get a baseline, or zero-level, of the emissions present when there will be no cruise ships docked in the harbor. Looking at the difference in levels from when there are several ships and no ships in the harbor, we will understand the significance of the cruise ship emissions.

Sincerely,

Shane Bellingham, Cortney Davis, Chris O’Brien and Erin Saari
Venice Project Center at the Worcester Polytechnic Institute, USA