Cruise Line Wastewater Discharge in the Caribbean Region

By

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Abstract

Cruise ship vacations provide a source of worldwide recreation for over 11 million passengers annually. However, there is particular concern over the cumulative environmental impacts these vessels have on the marine environment. Recognizing the need to address the health of the marine environment, Conservation International and the Cruise Lines International Association worked together to implement changes in wastewater discharge practices. The present Masters Project addresses the policy issues associated with wastewater discharge in the Caribbean region and presents recommendations for future mitigation of this environmental threat. It also presents the results of a geospatial analysis of current discharge regulations and provides maps to guide future management decisions. The goal of this geospatial analysis is to help develop and promote best practices concerning wastewater discharge by cruise ships in the Caribbean region.

Introduction

Each year the cruise line industry makes billions of dollars degrading the product on which it depends—the marine environment. "Graywater" from sinks, showers, galleys, and cleaning activities can contain detergents, oil and grease, and food waste; it is the largest source of liquid waste generated by cruise ships (Sweeting and Wayne 2003). A 7-10 day cruise can produce and dump over 1 million gallons of graywater into the ocean. "Blackwater" from toilets, urinals, and infirmaries is an even greater concern-- cruise ships can generate 8,000 – 21,000 gallons of blackwater per day (Sweeting and Wayne 2003). Even though ships are required to treat their wastewater, the human waste products generated and disposed of on these cruises may impact the environment. There is particular concern over cumulative environmental impacts caused by repeated visits to the same sensitive areas (USCOP 2004b).

While it is true that cruise lines are ultimately impacting the oceans, they are not doing so with malicious intent. In fact the nature of the cruise line industry depends on the health of the environment. Passengers do not want to see polluted water, degraded habitat, and contaminated beaches (Sweeting and Wayne 2003). Many cruise lines have realized the importance of working together to build a foundation for regulation of the industry. Royal Caribbean and Carnival Cruise Lines (after merging with P&O Princess cruise line in 2003) constitute roughly two-thirds of the cruise line market. These lines, among many others, have recently taken the initiative to implement practices, test and refine new technology, and go beyond current requirements to minimize their environmental footprint (Sweeting and Wayne 2003). However, the fact that there were 87 confirmed incidences of illegal discharge between 1993 and 1997 and several cases of falsifying oily bilge records as recently as 2002 means that there is still work to be done.

Scientists and environmental groups worry that the local impacts of cruise ships can be significant, especially in sensitive areas. The Caribbean is the destination for about half of the cruise line industry activity (Sweeting and Wayne 2003). As such, it is important to study localized impacts in sensitive marine areas of the Caribbean. The most acute problem is the proximity of discharged wastewater to corals and other sensitive habitats in the Caribbean region.

Industry standards on dumping in the oceans are set by the Cruise Lines International Association (CLIA). Members of CLIA hold themselves to high standards of waste discharge on cruise ships. Conservation International, in conjunction with the Center for Environmental Leadership in Business, is working with the CLIA to reduce or eliminate discharge in and around important marine structures, such as bathymetric features, coral reefs, and seagrass beds, in the Caribbean. Ultimately, good environmental practices will allow the industry to attract consumers who are seeking more environmentally responsible choices (Sweeting and Wayne 2003). The current paper addresses the policy issues associated with wastewater discharge in the Caribbean region and presents some policy recommendations for future management. It also presents the results of a geospatial analysis of current discharge regulations and provides maps to guide management decisions.

Policy Analysis

The policy issues involved with wastewater discharge include three main aspects of ecology: biophysical, human, and institutional. The biophysical ecology includes the coral reefs and organisms that live within them, pelagic vertebrates and invertebrates that live in the Caribbean region, human swimmers and divers, and inhabitants of the islands and coastal areas that use the water for sustenance. Cruise ships can carry over 5,000 passengers and crew, and produce tons of waste each day (Klein 2005). Blackwater and graywater can total over 480,000 gallons per day (30,000 black and 450,000 gray) on a full cruise. In addition, hazardous waste, solid waste, diesel exhaust, oily bilge water, and ballast water are also produced in large amounts on a daily basis. Wastewater discharge releases excessive nutrients into the water (Sweeting and Wayne 2003). These nutrients can over-stimulate aquatic plants and algae in the process of eutrophication. When eutrophication is prolonged, corals die due to the imbalance of nutrients and the reduced light available to symbiotic zooxanthellae within the corals. As corals die, the diverse groups of organisms that live among them also leave the area or die, resulting in a decrease in biodiversity. Ultimately, the change in ecological structure of marine communities can affect the use of the water for fishing and swimming, among other activities (Sweeting and Wayne 2003).

Wastewater can also contain harmful bacteria, such as fecal coliform, if not properly treated before discharge; this can directly cause health problems for residents of the area. Marine sanitation devices (MSDs) are required by law for all vessels with installed toilet facilities. They are designed to "receive, retain, treat, or discharge sewage and any process to treat such sewage" (EPA 2007b). There are three recognized types of MSDs: Types I, II, and III. A Type I is a flow-through treatment device which uses maceration and disinfection to treat sewage; they are used on vessels less than 65 feet in length. Type II MSDs are flow-through devices that use biological treatment and disinfection, though some use maceration also. Type II MSDs can be used on any size vessel. Type III MSDs serve as holding tanks that store sewage until it can be disposed of at a shore-side pumpout facility or at sea, three miles beyond shore (EPA 2007b). Once installed, MSDs must pass Coast Guard inspection (or similar International standards) to become certified for five years. In addition to MSDs, Advanced Wastewater Treatment Systems (AWTs, or Advanced Wastewater Purification Systems, AWPS) can be used to treat waste from ships. Detailed methods are discussed later, but generally AWTs "provide improved screening, biological treatment, solids separation (using filtration or floatation), disinfection (using ultraviolet light), and sludge processing" when compared with Type II MSDs (EPA 2007b). Through the proper use of both MSDs and AWTS, the cruise line industry can help ensure that residents of coastal communities in the Caribbean are not at high risk for diseases caused by contaminated water.

A primary concern when considering wastewater discharge is the destruction of biodiversity hotspots. Concern for biodiversity hotspots makes the discharge of wastewater a particularly important issue for the Caribbean. Biodiversity hotspots are ranked by the Center for Applied Biodiversity Science using a prioritization system of threat to species (Sweeting and Wayne 2003). Classifications include: the largest threat to the greatest number of species; the greatest diversity of endemic species; and having been significantly altered and impacted by human activities. Over 70 percent of cruise destinations are biodiversity hotspots, including the Caribbean. About half of the world's passengers on cruise ships that depart from U.S. ports travel to the Caribbean. Thus, environmental groups and scientists must investigate the possible effects of wastewater discharge in the Caribbean because it is such a biologically important area.

The human ecology of this issue deals with the following groups: coastal residents, ocean and coastal industries including consumers, and environmental interest groups. The Caribbean Region provides a home for almost 40 million people (Williams 2007). These residents may be directly impacted, both positively and negatively, by cruise line activity. Their homeland economies are boosted by tourists and cruise lines, but their environment can be damaged by the huge influx of people. The cruise line industry is one of the fastest growing industries. Between 1970 and 1998, the number of worldwide passengers grew from 500,000 to 9.5 million (Sweeting and Wayne 2003). In 2005, it boasted 11 million passengers (Sweeting, et al. 2006). The industry is expected to grow to 14.2 million passengers by 2010 (Sweeting and Wayne 2003). Between 2000 and 2004, 62 ships were added into the North American market, and another 21 ships are expected by 2009 (Sweeting, et al. 2006).

Several interest groups are concerned with the cruise line industry. The International Council of Cruise Lines, or ICCL, is comprised of over 100 ships, about two-thirds of the world's cruise ships and five percent of all passenger ships (Sweeting and Wayne 2003). The ICCL members account for 90 percent of the North American passenger cruise industry. In 2007, the ICCL merged with the Cruise Lines International Association (CLIA) to promote cooperation among the cruise lines in the industry and environmental groups (Rogers, pers. comm.). One environmental group facilitating dialogue between cruise lines and the environmental community is Conservation International (CI). This organization aims to "conserve the Earth's living natural heritage, our global biodiversity, and to demonstrate that human societies are able to live harmoniously with nature" (Sweeting and Wayne 2003). As a branch of Conservation International, the Center for Environmental Leadership in Business (CELB) has also been instrumental in changing business practices to lessen human impact on the environment. The dialogue and work between CI, CELB, and CLIA has been invaluable in changing the way the cruise line industry operates with respect to wastewater discharge.

Other environmental groups specifically associated with the cruise industry in the Caribbean have worked to ensure the integrity of their ocean and coastal communities. The Carnival and the SeaKeepers Society installs scientific devices on ships to gather and monitor ocean water quality (Sweeting, et al. 2006). The Florida-Caribbean Cruise Association's Foundation for the Caribbean helps 13 member cruise lines "fund humanitarian causes and improve the lives of people in the Caribbean" and includes disaster relief and environmental education (Sweeting, et al. 2006). The Cayman Islands Tourism Association was formed in the 1980s to prevent damage to marine life from water sports. Today this association continues to mark diving sites with buoys and discourage anchor use near reef habitat. This Association was incorporated into the Department of Environment in the Cayman Islands, which issues legislation and penalties for disobeying anchor use guidelines. The Belize Protected Area Conservation Trust gives small grants to NGOs and government agencies that are involved in conservation and management of protected areas. The Trust receives revenue from the cruise industry in the form of taxes per tourist or trip. Reef Check is a conservation group of volunteers that monitors, manages, and protects coral reefs, as well as provides education to passengers on Carnival cruise ships. The National Marine Sanctuary (NMS) Foundation collaborates with the NMS Program on the Florida Keys Eco-Discovery, which promotes research and education in the Florida Keys. The Reef Ball Foundation restores reefs through awareness and artificial reef planting. In addition there are several local stakeholder environmental groups that participate in education and conservation measures. These include: Norwegian Cruise Line America's water pollution education program, Princess Kids "Edutainment" programs, Disney Wildlife Conservation Fund, ICCL's Cruise Industry Charitable Foundation, and Royal Caribbean's Ocean Fund (Sweeting, et al. 2006).

Institutional ecology of the issue involves both the U.S. national and international policy instruments. In the United States, local governments are responsible for maintaining ports and providing sustainable attractions and services that can raise revenue and improve the quality of life for residents (Sweeting, et al. 2006). Governments can use policy instruments such as financing tools and incentives to cruise lines to support sustainable tourism. U.S. entities responsible for oversight of the cruise line industry include the U.S. Coast Guard, the Environmental Protection Agency, the National Security Council, the National Ocean Council, and Congress and state governments. The U.S. EPA is responsible for evaluating current performance of MSDs and AWTS to determine whether revisions or additional standards for sewage and graywater discharge are necessary (EPA 2007b). In addition, the U.S. Coast Guard developed regulations pertaining to discharge in Alaskan waters and is reviewing its inspection and enforcement policies. The California National Marine Sanctuaries are proposing to prohibit cruise ship discharge within NMS waters (EPA 2007b). One example of national oversight in the Caribbean is the U.S. Virgin Islands National Park. This park requires a daily user fee and implements extensive training to ensure that its staff is effective. It also requires new commercial plans to be evaluated for potential impacts on the area and marine life (Sweeting, et al. 2006).

At the international level several organizations are responsible for regulating ocean activities. The International Maritime Organization (IMO) is responsible for maritime safety and security and preventing pollution from ships by setting international standards; the IMO developed conventions "creating liability and compensation regimes for damages arising from vessel-related pollution" (USCOP 2004a). The Intergovernmental Oceanographic Commission (IOC) is part of United Nations Educational, Scientific and Cultural Organization (UNESCO) and addresses coastal and ocean issues through sharing of information and technology. The IOC has a vested interest in global ocean observing systems. The United Nations Development Program helps countries address challenges related to energy, environment, and sustainable development. It launched the Strategic Initiative for Ocean and Coastal Management to bring together many agents and "enhance the effectiveness of ocean and coastal management projects in promoting sustainable human development in developing countries" (USCOP 2004a). The United Nations Environment Program enhances global understanding of environmental issues and oversees a variety of projects and initiatives dedicated to global, regional, and national cooperation and sustainable development. The UN Division for Ocean Affairs and Law of the Sea is responsible for fulfilling the functions associated with the Law of the Sea Convention. These international institutions promote cooperation in conservation efforts and increased compliance with international laws.

There are already in place several convention agreements that oversee the wastewater activities of ships around the world. The International Convention for the Prevention of Pollution from Ships (also known as MARPOL) contains six annexes which regulate different facets of pollution control: I (oil), II (noxious liquids carried in bulk), III (harmful substances carried in package form), IV (sewage), V (garbage from ships), and VI (air emissions). Only Annexes I and

II are mandatory and entered into force in 1983; the rest are optional and entered into force in 1992, 2003, 1988, and 2005, respectively. Annex IV entered into force in 2003 and has not been signed or ratified by the U.S. (USCOP 2004a). Annex IV of MARPOL speaks to the activities pertaining to sewage from ships. It includes regulations for discharging sewage into the sea, systems for the control of sewage discharge, and a model International Sewage Pollution Prevention Certificate to be issued by national shipping administrations. Annex IV also prohibits ships from discharging within a specified distance of land. This Annex specifically states that discharge will be prohibited "except when the ship has in operation an approved sewage treatment plant and is discharging comminuted and disinfected sewage using an approved system at a distance of more than three nautical miles from the nearest land; or is discharging sewage which is not comminuted or disinfected at a distance of more than 12 nautical miles from the nearest land" (IMO 2002).

Another form of international cooperation is the United Nations Convention on the Law of the Sea (UNCLOS). UNCLOS established an international constitution for the oceans, stating the rights, duties, and responsibilities of each nation within its territorial sea, Exclusive Economic Zone, continental shelf, and high seas. It also created institutions for managing ocean issues and provides mechanisms for settling disputes (USCOP 2004a). UNCLOS is a comprehensive law for the oceans comprised of 320 articles and 9 annexes. It addresses delimitation, pollution control, scientific research, resource management, technology transfer, and dispute settlement. The agreement was reached in 1982, but not put into force until 1994. The U.S. has not signed or ratified it (USCOP 2004a).

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, also called the London Convention, regulates the disposal of waste materials in the sea and established the “black and gray” lists for wastes that can be disposed at sea. This convention went into force in 1975 and is signed and ratified by the U.S. (USCOP 2004a). The Protocol to the London Convention created a more restrictive, precautionary approach for dumping wastes into the ocean. It was agreed upon in 1996 and entered into force in 2006 (IMO 2002).

The United States, although it may not have ratified all international conventions, still holds itself to high standards in the way of wastewater restrictions. The Federal Water Pollution Control Act of 1972 (Clean Water Act) set regulations for the discharge of pollutants into U.S. waters. It gave the Environmental Protection Agency (EPA) authority to implement pollution control programs such as setting standards for wastewater discharge. According to the Clean Water Act, which also sets the standards for contamination levels in surface water, vessels must obtain National Pollutant Discharge Elimination System permits to discharge sewage into navigable waters. The regulation of effluent discharge by the CWA, as it pertains to the cruise line industry, is concerned with the effects of discharge on marine life including plankton, fish, shellfish, and biological processes (EPA 2007a). The CWA mandates that the EPA develop marine sanitation device (MSD) technology for the treatment of sewage on board vessels that have toilets to ensure that effluent is similar to effluent from land-based wastewater treatment plants (Sweeting and Wayne 2003).

There are additional laws that protect the nation’s water, including the Resource Conservation and Recovery Act of 1976 and the Ports and Waterways Safety Act of 1972, revised in 2006. The RCRA deals mostly with terrestrial issues, but could be helpful in creating overarching legislation to guide wastewater discharge from ships. Its goals are to protect oceans from the hazards of waste disposal, conserve energy and natural resources by recycling and recovery, reduce or eliminate waste, and clean up waste, which may have spilled, leaked, or been improperly disposed (EPA 2007a). The Ports and Waterways Safety Act recognizes that "increased vessel traffic in the Nation's ports and waterways creates substantial hazard to life, property, and the marine environment" (Office of the Law Revision Council 2006). This Act aims to prevent damage to the marine environment in port areas, which is also a factor in the cruise line industry, although less so than wastewater itself. There are also various state laws that affect the cruise industry. For example, Florida, Hawaii, and Washington issued memoranda of understanding which rely on voluntary compliance of cruise lines with state regulations (Klein 2005).

The primary body concerned with self-regulation of the cruise ship industry is the Cruise Lines International Association (CLIA 2006). When this body merged with the International Council of Cruise Lines (ICCL), it became a major regulating force in the industry. Members of the CLIA are committed to: designing, constructing, and operating vessels to minimize impact on the environment; improvements in technology that exceed requirements; reducing shipboard waste, including a zero discharge of MARPOL Annex V solid wastes and near compliance with U.S. regulations; reuse and recycling as part of a waste-reduction strategy; improving processes and procedures to handle hazardous wastes; comprehensive monitoring programs and onboard auditing of environmental practices in accordance with ISM code; and working with the U.S. Coast Guard and the EPA to implement these commitments (CLIA 2006). The waste stream management standards include the following:

1. Minimize silver discharge in photo-processing
2. Prevent discharge of dry-cleaning waste by-products
3. Prevent discharge of hazardous waste from ink and cleaning chemicals in print shops
4. Maximize return of laser print cartridges for recycling
5. Safely dispose of unused and outdated pharmaceuticals
6. Prevent the release of mercury and assure proper recycling of vapor lamp bulbs
7. Prevent the discharge of batteries into the environment
8. Meet or exceed international requirements for removing oil from bilge and wastewater

prior to discharge.

9. Comply with MARPOL Annex V and maximize recycling of glass, cardboard, aluminum, etc.
10. Reduce the production of incinerator ash by minimizing waste/maximizing recycling
11. Discharge graywater only while the ship is underway, traveling greater than six knots, and not discharge in ports or within 4 nautical miles of shore or some other agreed distance
12. Process blackwater through an MSD and discharge while underway going greater than six knots and at least 4 nautical miles from land

In addition to these standards, many of the cruise lines in the CLIA are testing or using Advanced Wastewater Purification Systems (AWPS) to produce high quality effluent that is not subject to strict discharge limitations (CLIA 2006). Some cruise lines, like Celebrity, also utilize reverse osmosis to clean wastewater; others, like Carnival, are testing Rochem ultrafiltration systems that use biological processes to treat water (Sweeting and Wayne 2003). Other technologies and methods of wastewater treatment that show potential include nutrient removal, metals removal, and temperature control (EPA 2007b). Nutrient removal methods include: ammonia removal by biological nitrification; total nitrogen removal by ion exchange; and phosphorus removal by chemical precipitation. Metals removal technology includes the use of ion exchange and reverse osmosis. Temperature control technology advancements using a shell and tube heat exchanger would help to more efficiently cool effluent. Through all these measures, the CLIA helps to encourage self-regulation and environmentally-friendly practices in the cruise line industry.

As time progresses, the cruise line industry will need to take measures to ensure that it has a “product” left to sell. If the industry moves forward without exploring new wastewater treatment technology, the cruise lines will damage the marine life that draws customers in the first place. Thus, the CLIA plays a vital role in maintaining the industry and continuing tourism and education. Accordingly, cooperation among local stakeholders and government and environmental groups must be transparent, open to negotiation, and have an awareness of long-term sustainability issues (Sweeting, et al. 2006). Dialogue between Conservation International, the Center for Environmental Leadership in Business, and the Cruise Lines International Association has resulted in some possible policy alternatives to address the problem of wastewater discharge in the Caribbean region.

Beginning in 2006, CI began an effort, partnering with CELB, CLIA, and Duke University, to encourage cruise lines to take a firmer stance on wastewater discharge—one that would require more work on the part of the cruise lines, but that would ultimately benefit everyone (Thomas 2007). An independent Science Panel convened by the Ocean Conservation and Tourism Alliance gathered to evaluate the problem of cruise ship wastewater discharge and make some recommendations about how to improve discharge practices. The Science Panel made a total of 11 recommendations revolving around wastewater treatment and discharge. These recommendations include using Marine Sanitation Devices or Advances Water Purification Systems to treat blackwater. Blackwater treated by an MSD is currently required to be discharged at least four nautical miles from the 20-meter depth contour line. Improved practices would include discharging this wastewater at least 12 nm from the 20-m depth contour and 4 nm from sensitive marine habitat such as corals and shellfish beds (OCTA Science Panel 2006). The Panel also recommends that blackwater treated by an AWPS should be discharged at least one nautical mile from the 20-m depth contour and sensitive marine habitat. Another suggestion was that cruise ships not discharge untreated graywater less than four nautical miles from the 20-m depth contour line. However, the improved alternative practice would be to use an MSD or AWPS to treat graywater and discharge at least 12 nm from the 20m depth contour and sensitive marine habitat. Overall, best practices would include continued installation of the more rigorous AWPS technology on more ships to treat all wastewater before discharge.

Change will only occur when the cruise lines and environmental and government groups agree on a solution that is both feasible and enforceable. As part of my evaluation of the best alternative solutions, I recommend the following actions be taken concerning wastewater discharge in the Caribbean:

1. Congress should establish a regime for managing wastewater discharges in the United States with uniform standards and waste management procedures; recordkeeping; sampling, testing, and monitoring of water quality using uniform protocol; and flexibility and incentives to encourage the development of new treatment technology. (USCOP 2004b)

2. Organizations should work to improve management systems so that they implement more and effective protected areas, stakeholder participation, local ownership, and restorations (Spalding and Kramer 2003).

3. Cruise lines should adopt the Science Panel Recommendations and utilize the maps, assimilating them into nautical charts, and continue cooperation with CI and CELB. International dialogue should remain open and transparent to be effective.

Without taking action, the cruise line industry will soon have no beautiful reefs and clean beaches for their customers. By working with the government and environmental groups, cruise lines can incorporate best management practices to decrease the detrimental impacts of wastewater discharge on sea life in the Caribbean.

Geospatial Analysis

In an effort to make the Science Panel recommendations more tangible, CI partnered with the Nicholas School of the Environment and Earth Sciences at Duke University to create a set of maps depicting these areas where discharge should be avoided. The Science Panel identified four focus areas (see Figure 1) that the mapping effort should evaluate: South Florida and the

Bahamas, the Cayman Islands, Puerto Rico and the Virgin Islands, and Mesoamerica (off the coast of Belize).

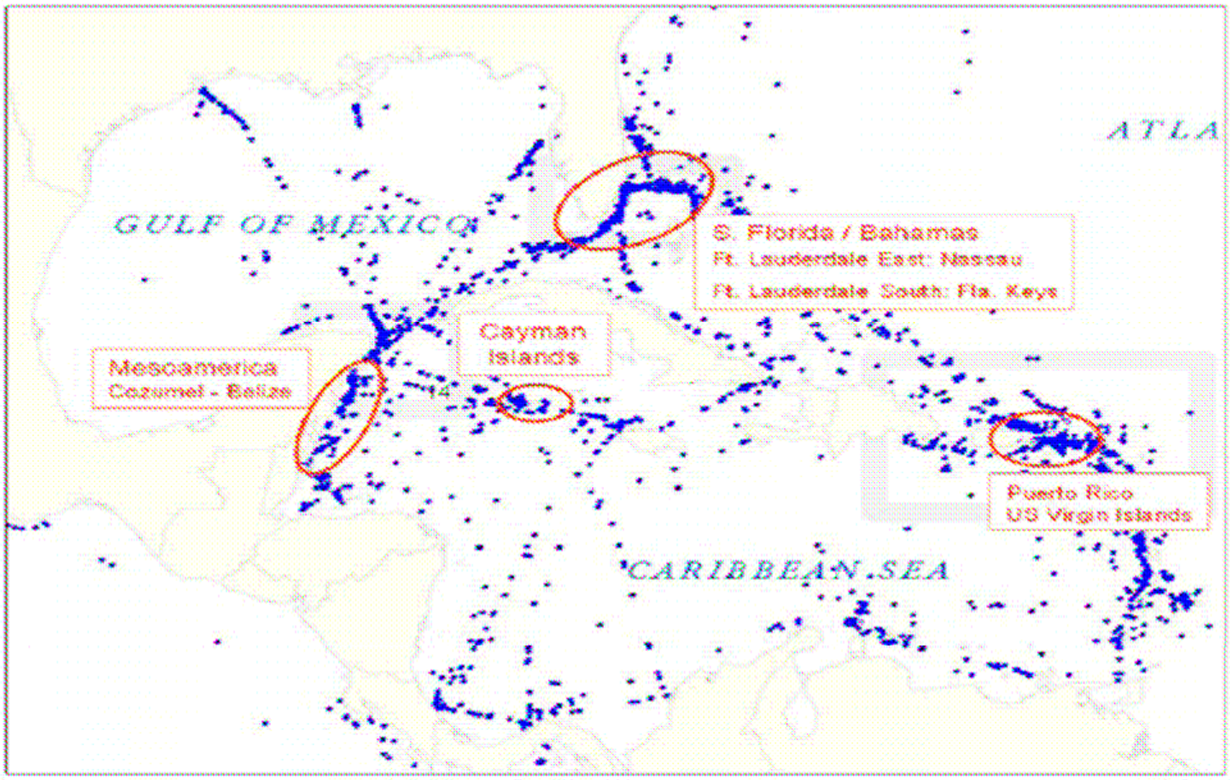


Figure 1. Areas of concern for effects of cruise line wastewater discharge on sensitive habitat in the Caribbean, as determined by the Science Panel Wastewater Recommendations (Halpin 2007).

Data

I gathered data to map places in the Caribbean where cruise lines should avoid wastewater discharge from a variety of sources. The data required for the analysis included: country locations, coral reef locations, sensitive marine habitat, marine protected areas, and bathymetric features near the locations of interest. All data were processed using ArcGIS 9.2 software. The country data was a straightforward data layer of all countries in the region of interest. The bathymetry data was cropped using the Single Output Map Algebra tool to include only places where water depth was less than 20 meters. Coral reef data (for reefs “at risk”) were available for the entire Caribbean region; however, detailed sensitive marine habitat data were only available for Florida, Puerto Rico, and the U.S. Virgin Islands. Therefore, coral reef and sensitive marine habitat data were combined only for those areas. Marine protected area (MPA) locations were available for the entire Caribbean region as well. I combined both point and polygon locations to give an overall picture of MPA locations. I converted all data layers used to a Lambert Conformal Conic (North American Datum 1983) projection before any analyses were performed.

Metadata

Data layer	**Original layer name**	**Data type**	**Scale/Resolution**	**Source**
Bathymetry	bath_dhi1k	Grid/raster	1 km	WRI
Reefs at risk	reef_locs	point	1:500,000	WRI
Reefs at risk	reef_500	Grid/raster	500 m	WRI
Reefs- Bahamas	reefbase_bhs_rl	point		ReefBase
MPA	mpa_pnt	Shapefile-point	unknown	WRI
MPA	mpa_poly	Shapefile (poly)	varied	WRI
MPA	fknms_py	Shapefile (poly)		NOAA/NMS Program
MPA	reefbase_bhs_mpa	Shapefile- point		ReefBase
Sensitive marine habitat	p_rico	Shapefile (poly)		NOS/NOAA
Sensitive marine habitat	Stc_fin Stsj_fin	Shapefile (poly)		NOS/NOAA

Discharge avoidance areas

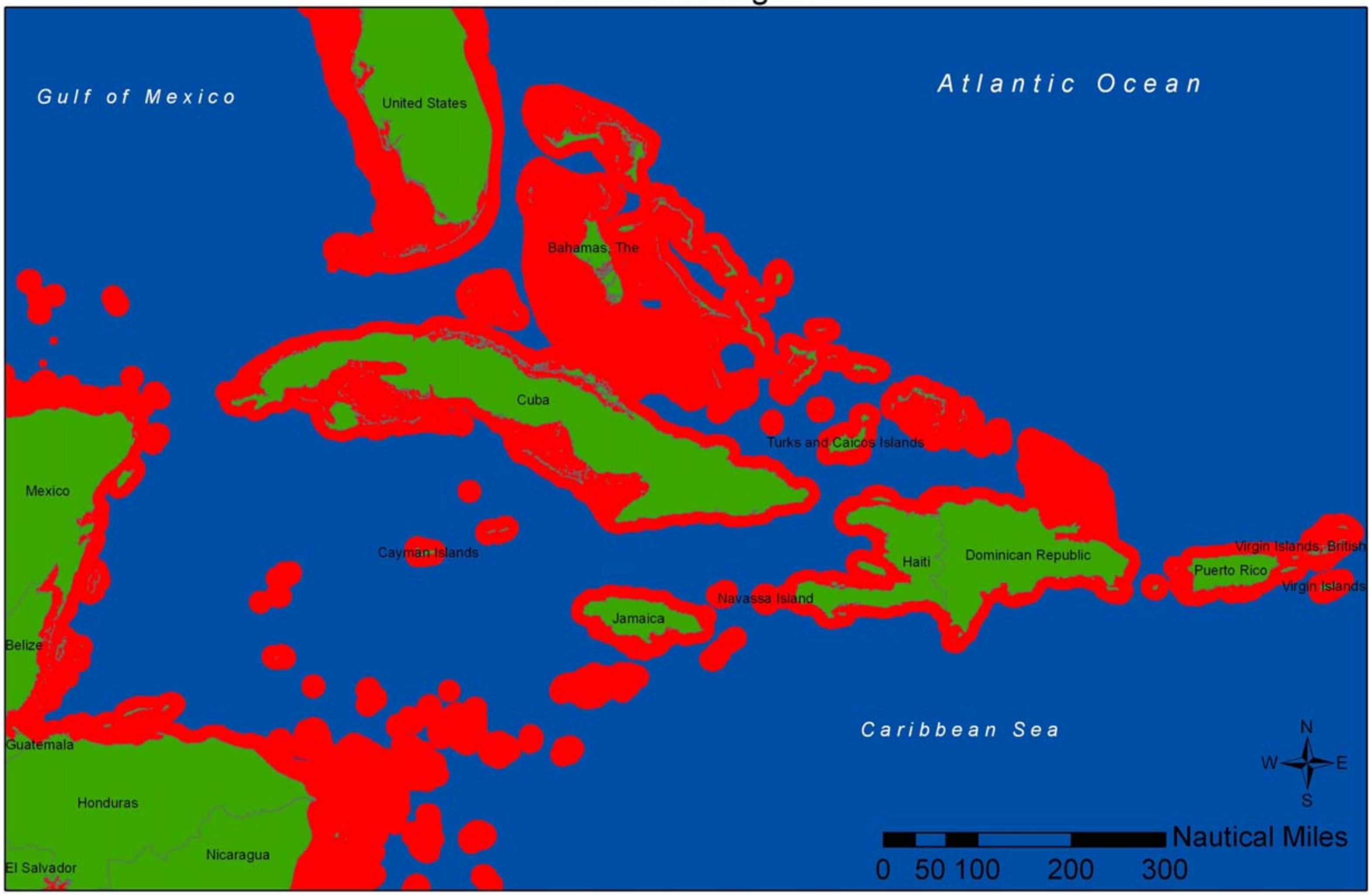
I used a Euclidean Distance tool to create a 500-meter grid layer of the bathymetry data. Using the new bathymetry layer, I again executed the Euclidean Distance function to approximate a 1-nautical mile (nm), 4 nm, and a 12 nm buffer from the 20-meter depth contour. The same was done for the reef location data. However, because multiple sources were available, in both raster and vector format, I had to convert all features to rasters before determining the 1, 4, and 12 nm buffers for coral reefs. I also converted all MPA shapefiles to rasters to be consistent in calculating buffers for discharge avoidance areas.

Due to the constraints of the resolution of the data layers, the buffers are a close approximation of those distances. One nautical mile equals 1,852 meters. Four nautical miles equal 7,408 meters. Twelve nautical miles equal 22,224 meters. After running the Euclidean Distance tool on 500m rasters, I ended up with 1,802.78m, 7,382.41m, and 22,209.23m as approximations of 1, 4, and 12 nm, respectively. For the scale of this analysis, these numbers were appropriate to use as overall guidelines on where discharge should be avoided. However in future analyses, finer scale data and better resolution will be necessary to remove this source of error and aid in producing detailed nautical charts for cruise ships to utilize.

Final products

To create the final maps for Conservation International, I combined buffers to show compliance with CLIA policy. Advanced water purification systems (AWPS) are required to discharge at least one nautical mile from both sensitive marine habitat, including reefs and marine protected areas (MPAs), and the 20m depth contour. I created maps of each of the four focus area for AWPS standards. Type II Marine Sanitation Devices are used in compliance with the CLIA standards of discharging at least 4 nm from sensitive marine habitat and at least 12 nm from the 20m depth contour. I created a map depicting these distances for the Caribbean region as a whole, as well as for each of the four focus areas.

MSD Type II systems
4 nm from Sensitive Marine Habitat and 12 nm from 20m depth contour
Caribbean region



Areas in red indicate where cruise ship wastewater discharge should be avoided due to proximity of the sensitive marine habitat and the 20m depth contour.

Projection: Lambert Conformal Conic

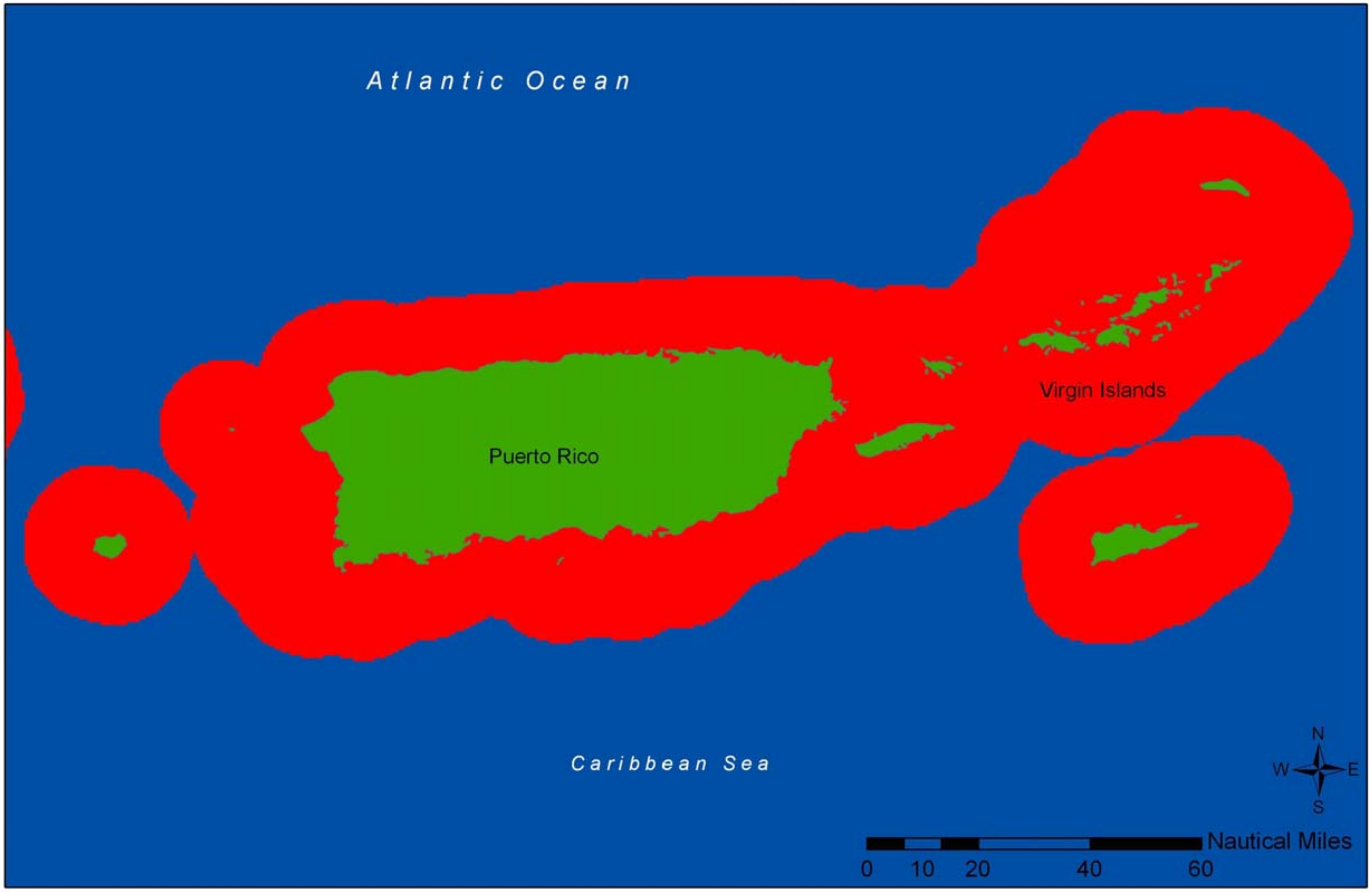
Map created by:
Pamela McCarthy
Duke University

Areas where discharge of MSD treated water should be avoided:
4 nm from Sensitive Marine Habitat and 12 nm from the 20m depth contour
South Florida and the Bahamas

Projection: Lambert Conformal Conic

Map created by:
Pamela McCarthy
Duke University

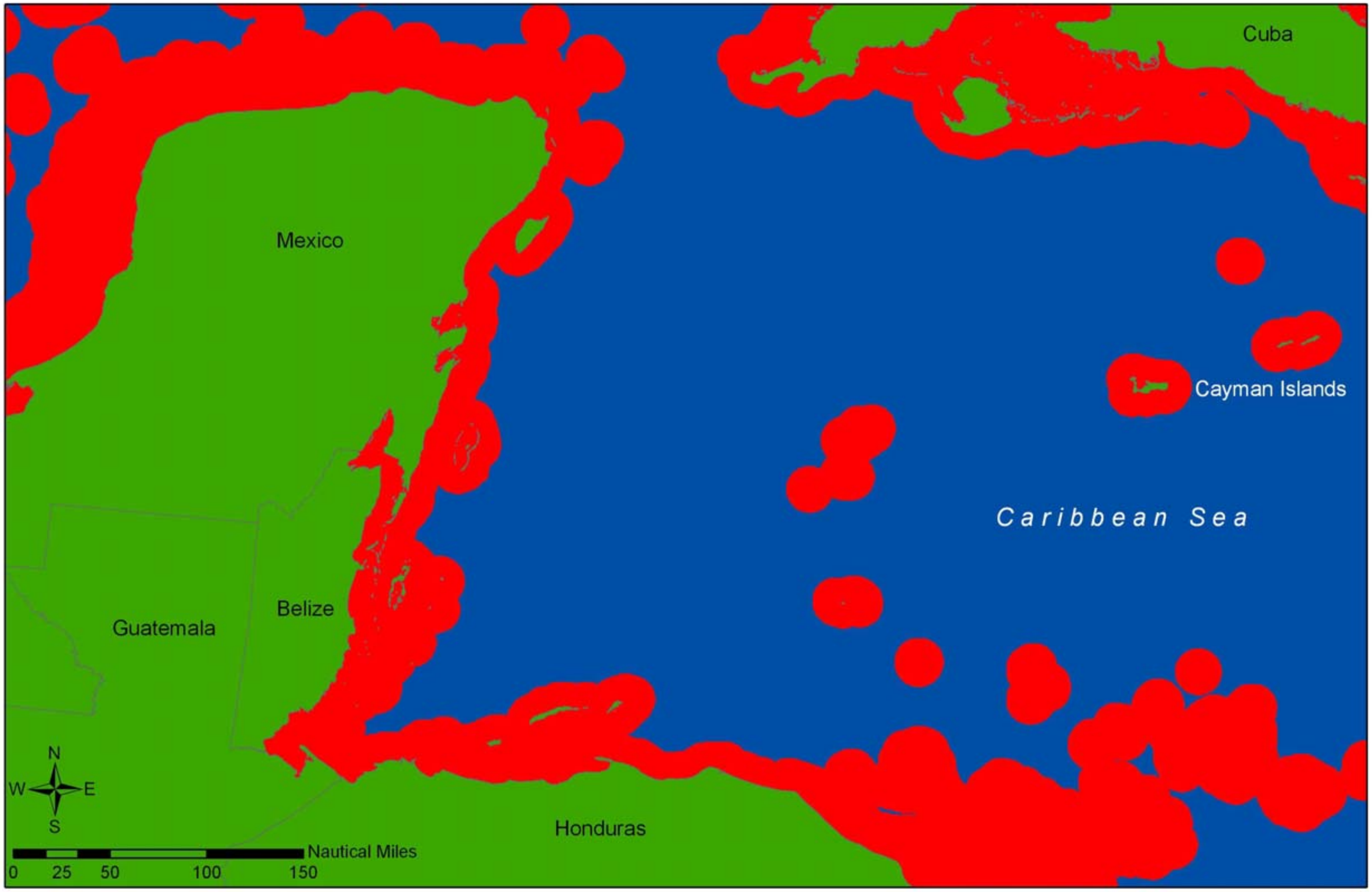
Areas where discharge of MSD treated water should be avoided: 4 nm from Sensitive Marine Habitat and 12 nm from the 20m depth contour Puerto Rico and the Virgin Islands



Projection: Lambert Conformal Conic

Map created by:
Pamela McCarthy
Duke University

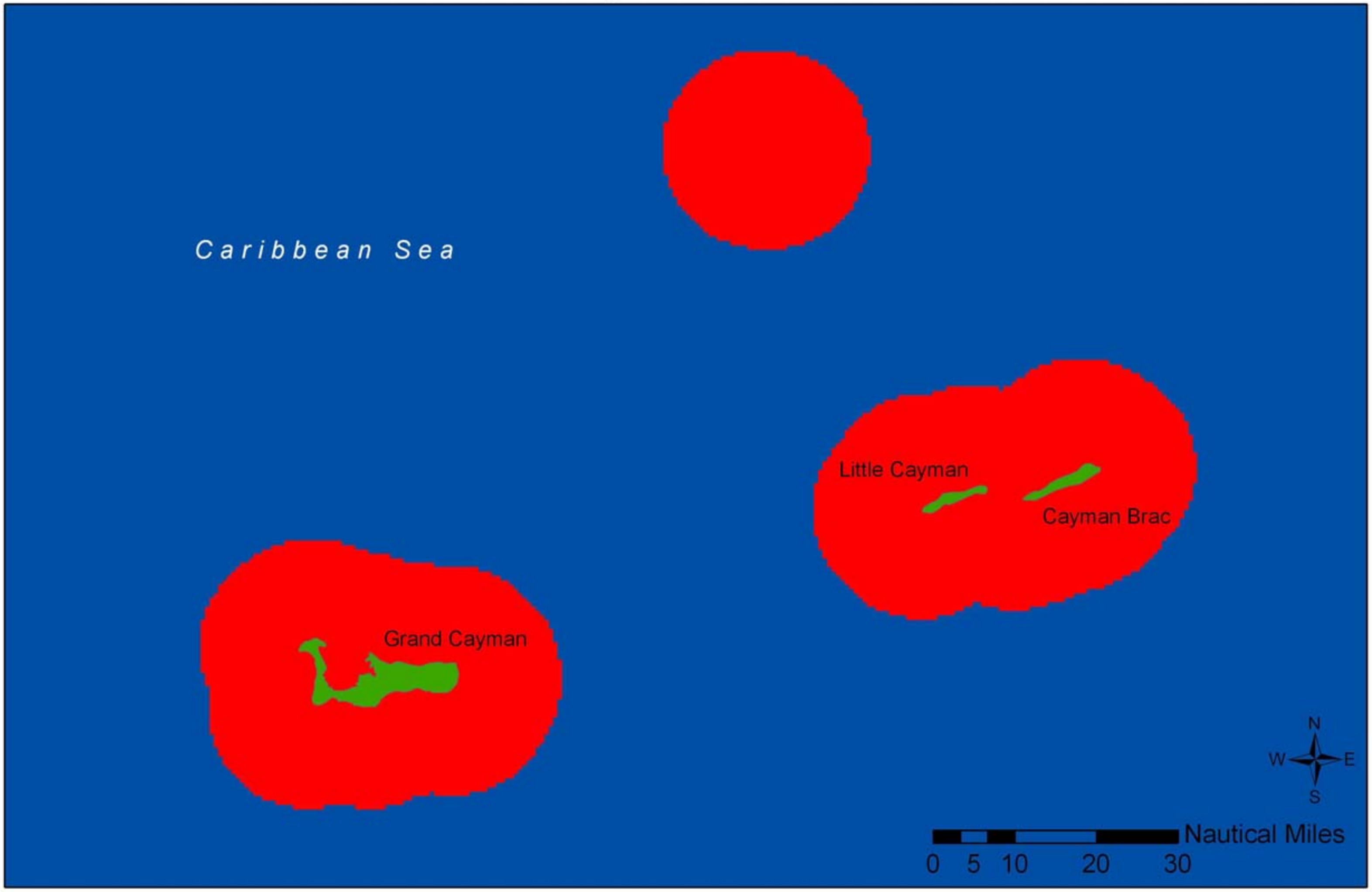
Areas where discharge of MSD treated water should be avoided: 4 nm from Sensitive Marine Habitat and 12 nm from the 20m depth contour Mesoamerica



Projection: Lambert Conformal Conic

Map created by:
Pamela McCarthy
Duke University

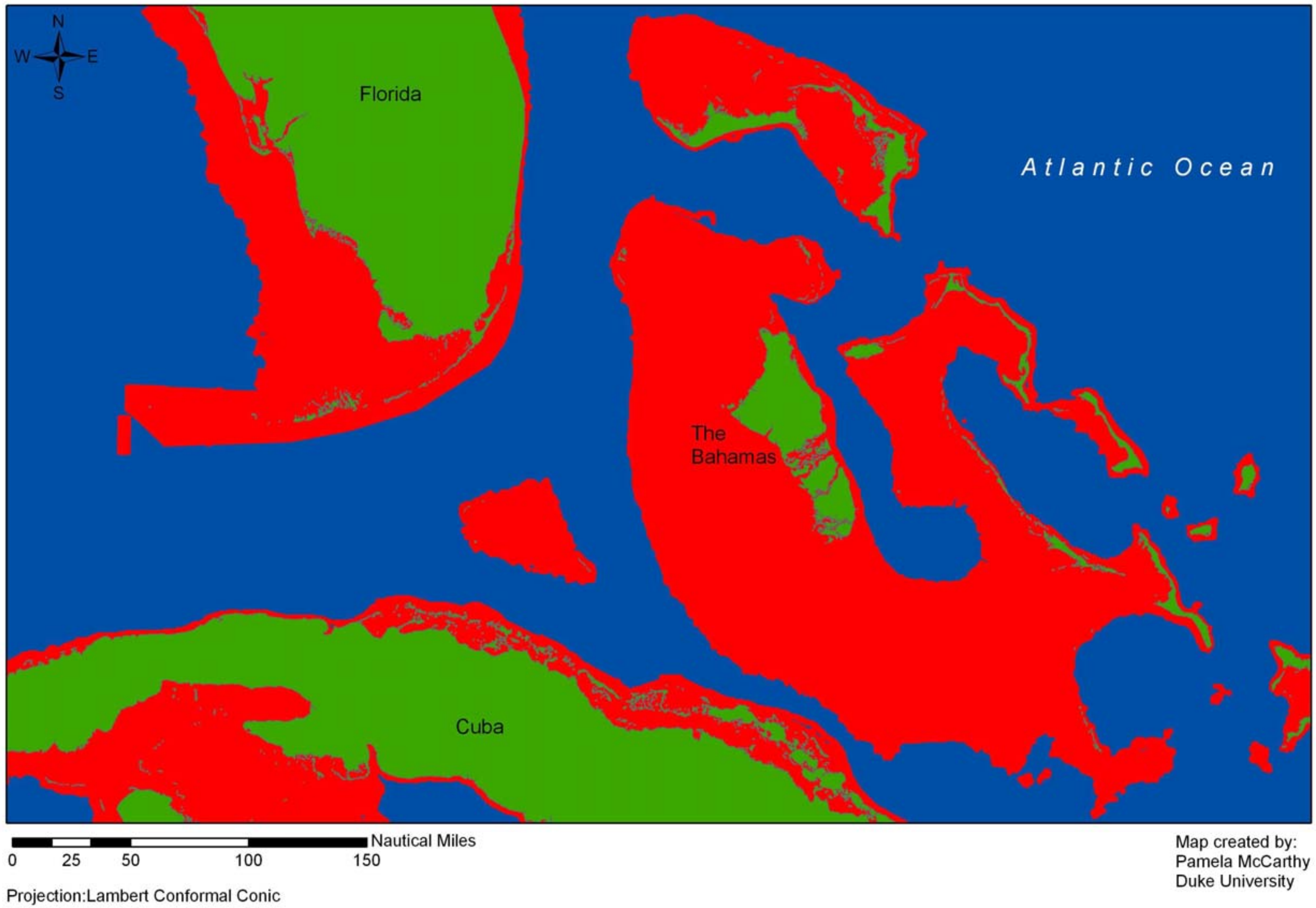
Areas where discharge of MSD treated water should be avoided:
4 nm from Sensitive Marine Habitat and 12 nm from the 20m depth contour
Cayman Islands



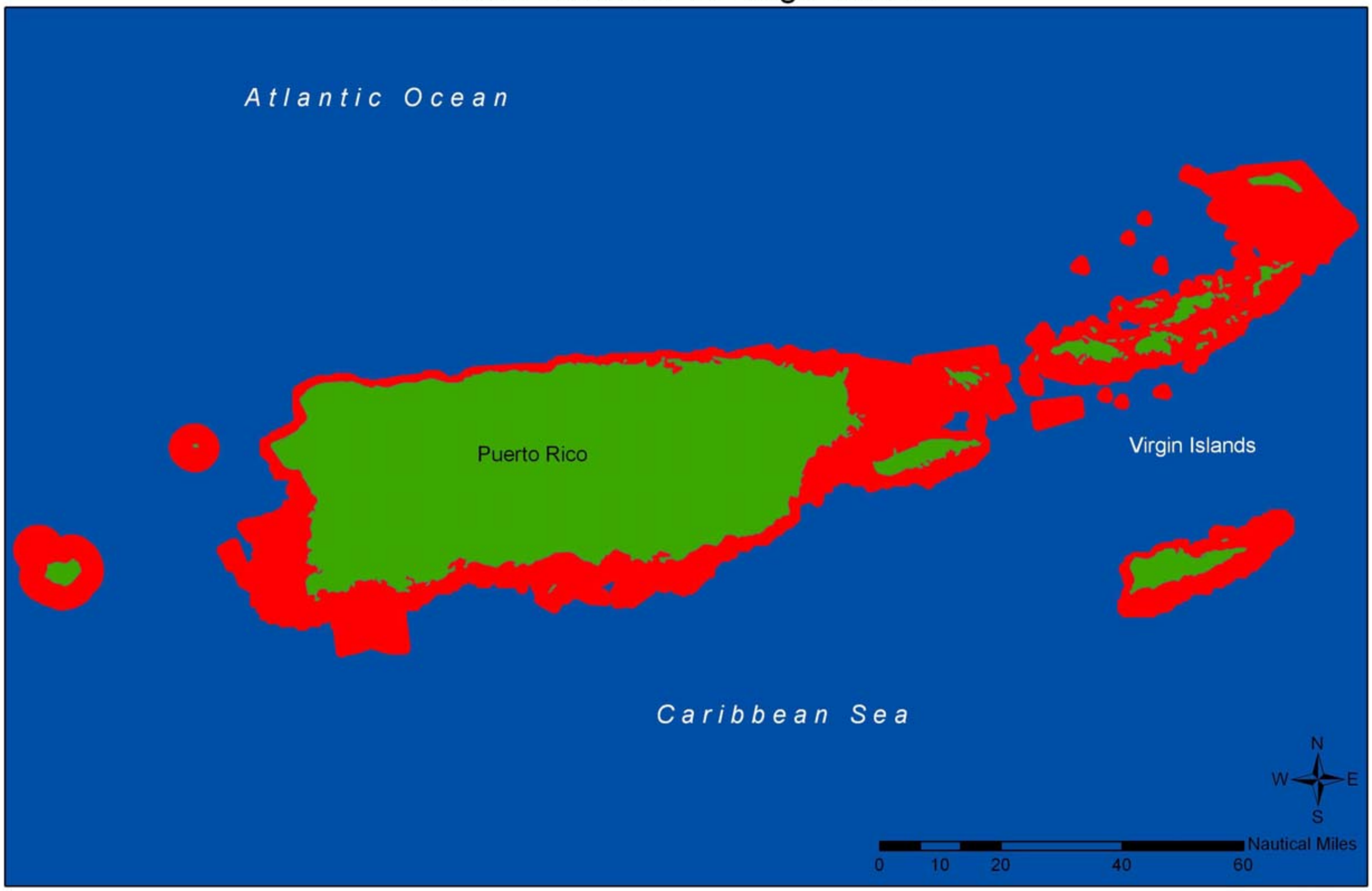
Projection: Lambert Conformal Conic

Map created by:
Pamela McCarthy
Duke University

Areas where discharge of AWPS treated water should be avoided:
1 nm from Sensitive Marine Habitat and 1 nm from the 20m depth contour
South Florida and the Bahamas



Areas where discharge of AWPS treated water should be avoided: 1 nm from Sensitive Marine Habitat and 1 nm from the 20m depth contour Puerto Rico and the Virgin Islands



Projection: Lambert Conformal Conic

Map created by:
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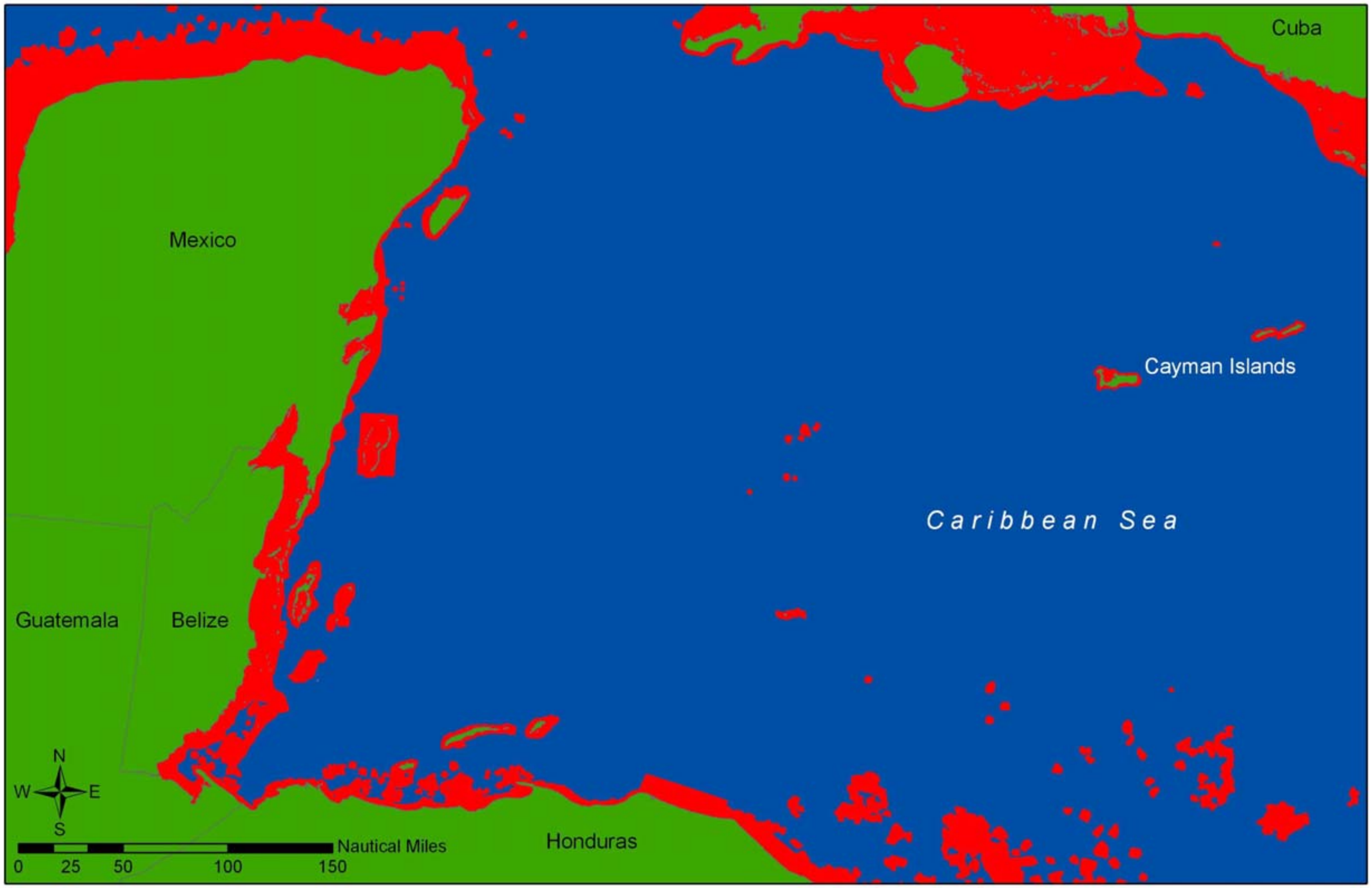
Areas where discharge of AWPS treated water should be avoided:
1 nm from Sensitive Marine Habitat and 1 nm from the 20m depth contour
Mesoamerica



Projection: Lambert Conformal Conic

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Areas where discharge of AWPS treated water should be avoided:
1 nm from Sensitive Marine Habitat and 1 nm from the 20m depth contour
Cayman Islands

Projection: Lambert Conformal Conic

Map created by:
Pamela McCarthy
Duke University

I also created additional maps to supplement the maps for Conservation International. These are attached in Appendix A and include the following: coral reefs, marine protected areas, and bathymetry of the Caribbean region; coral reefs of the Caribbean region with 4 and 12nm buffers; marine protected areas of the region with 4 and 12nm buffers; and bathymetry of the region with 4 and 12nm buffers. The supplemental maps were not used by Conservation International, but nonetheless provide an added level of understanding by examining the inputs of bathymetry, reef location, and marine protected areas.

The final steps were to apply these "no discharge zones" to nautical charts (found in Appendix A). Due to constraints of data availability, I was only able to create maps on nautical charts for three of the four focus areas (South Florida and the Bahamas, Cayman Islands, and Puerto Rico/U.S. Virgin Islands). It should be noted that these maps are not intended for navigational purposes due to the difference in scale and resolution between the discharge avoidance areas analysis and the nautical charts. These maps were presented to the CLIA in September of 2007 for consideration in their environmental practices.

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Appendix A

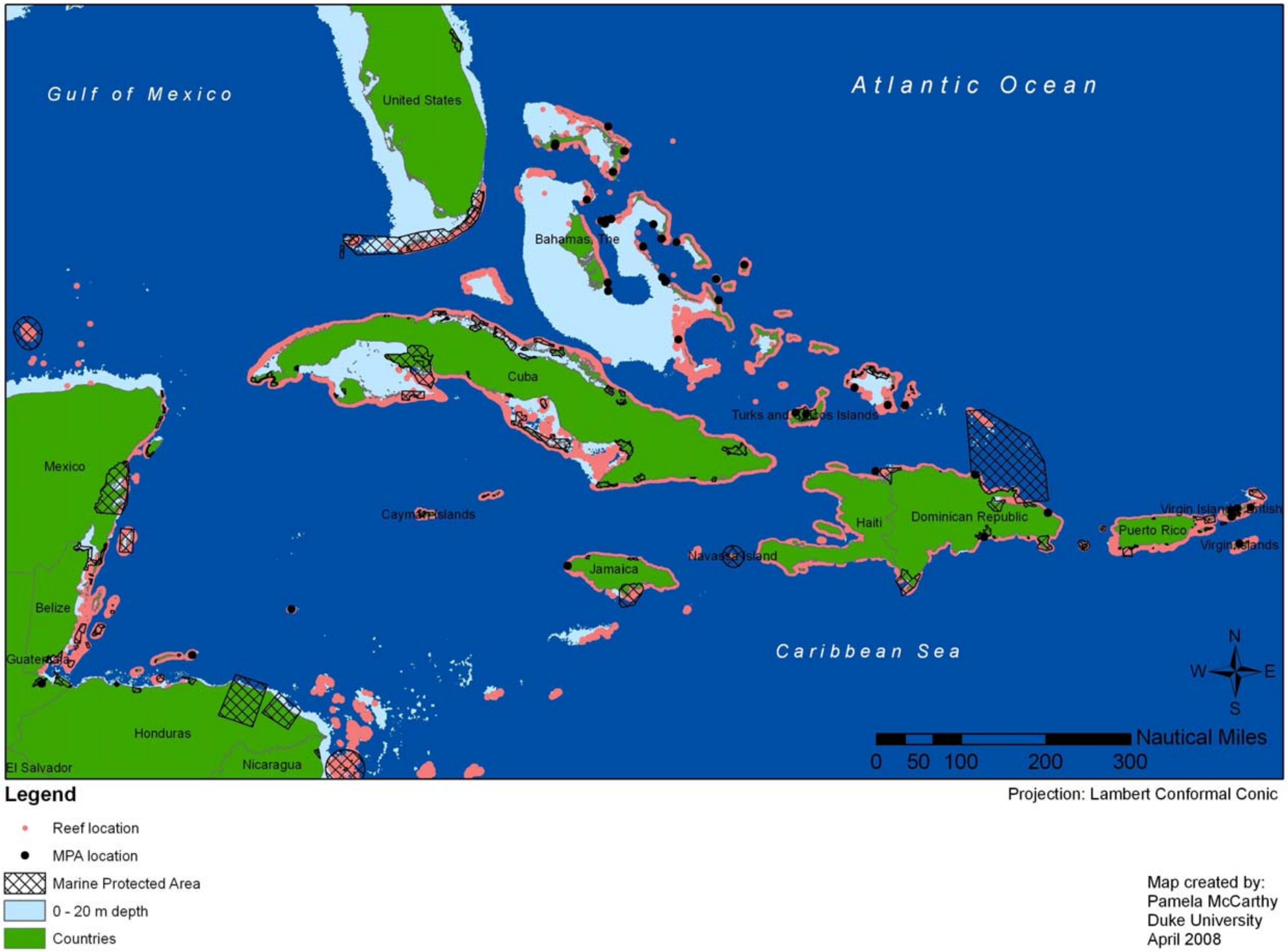
Supplemental maps for wastewater discharge in the Caribbean region

1. Coral reefs, marine protected areas, and bathymetry of the Caribbean region
2. Coral reefs—4 nm and 12 nm distances
3. Marine protected areas-- 4 nm and 12 nm distances
4. Bathymetry-- 4 nm and 12 nm distances

Sample nautical charts for wastewater discharge

1. Florida Keys
2. North Bahamas
3. South Bahamas
4. Puerto Rico
5. Virgin Islands
6. Cayman Islands

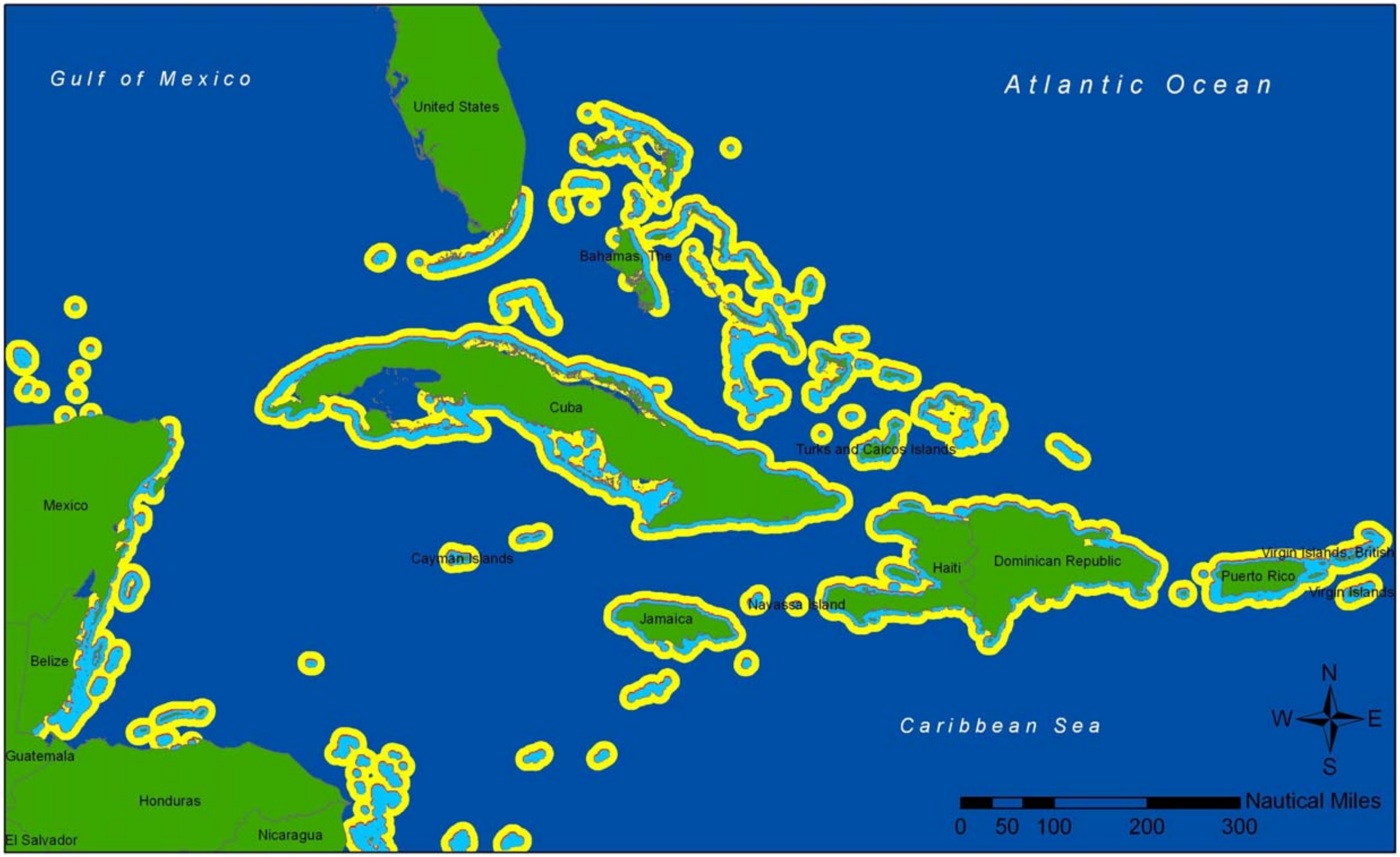
Coral Reefs, Marine Protected Areas, and Bathymetry of the Caribbean Region



Projection: Lambert Conformal Conic

Map created by:
Pamela McCarthy
Duke University
April 2008

Coral Reefs in the Caribbean Region
(4 nm and 12 nm from reef)



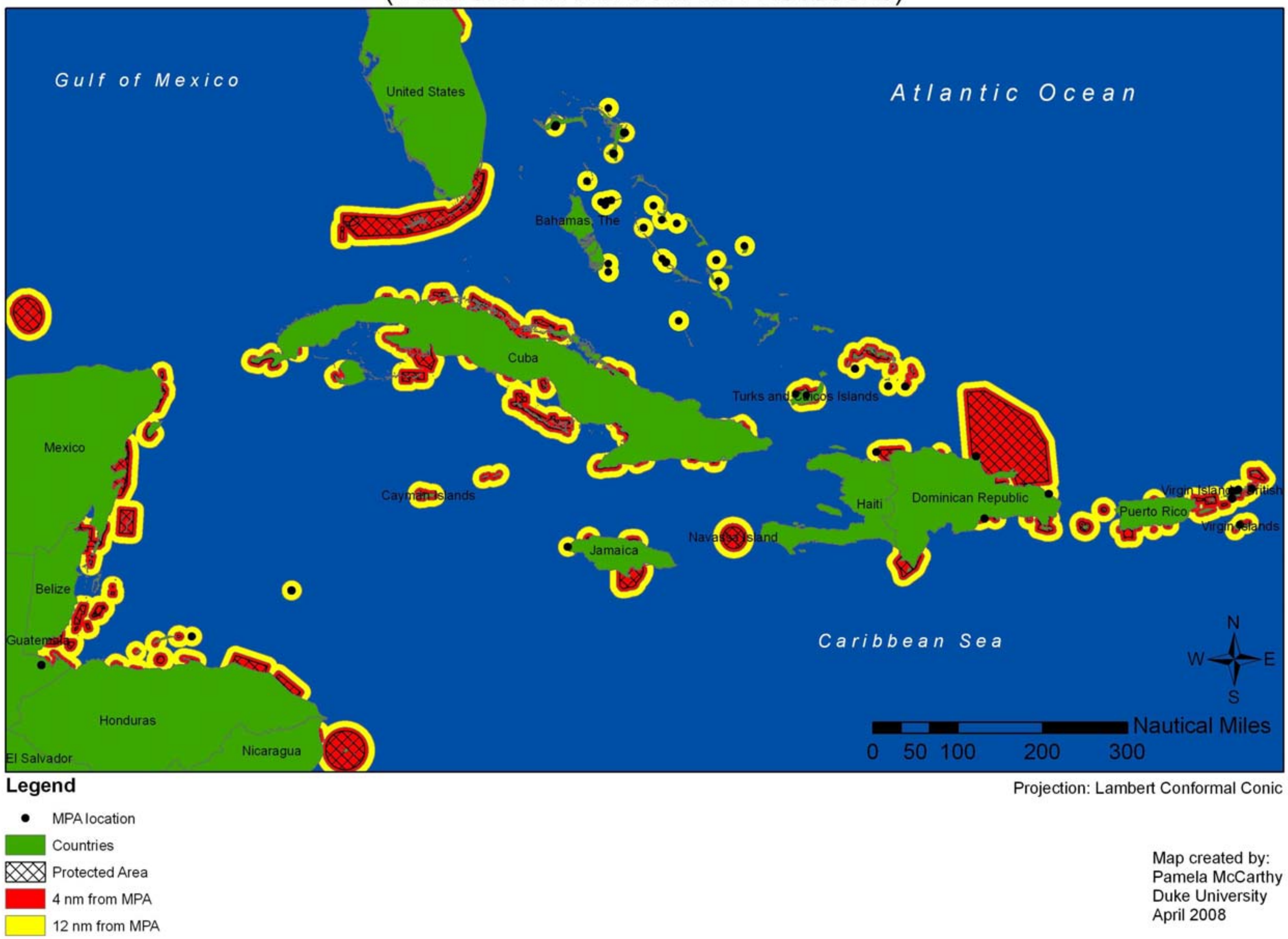
Legend

- Reef location
- Countries
- 4 nm from reef
- 12 nm from reef

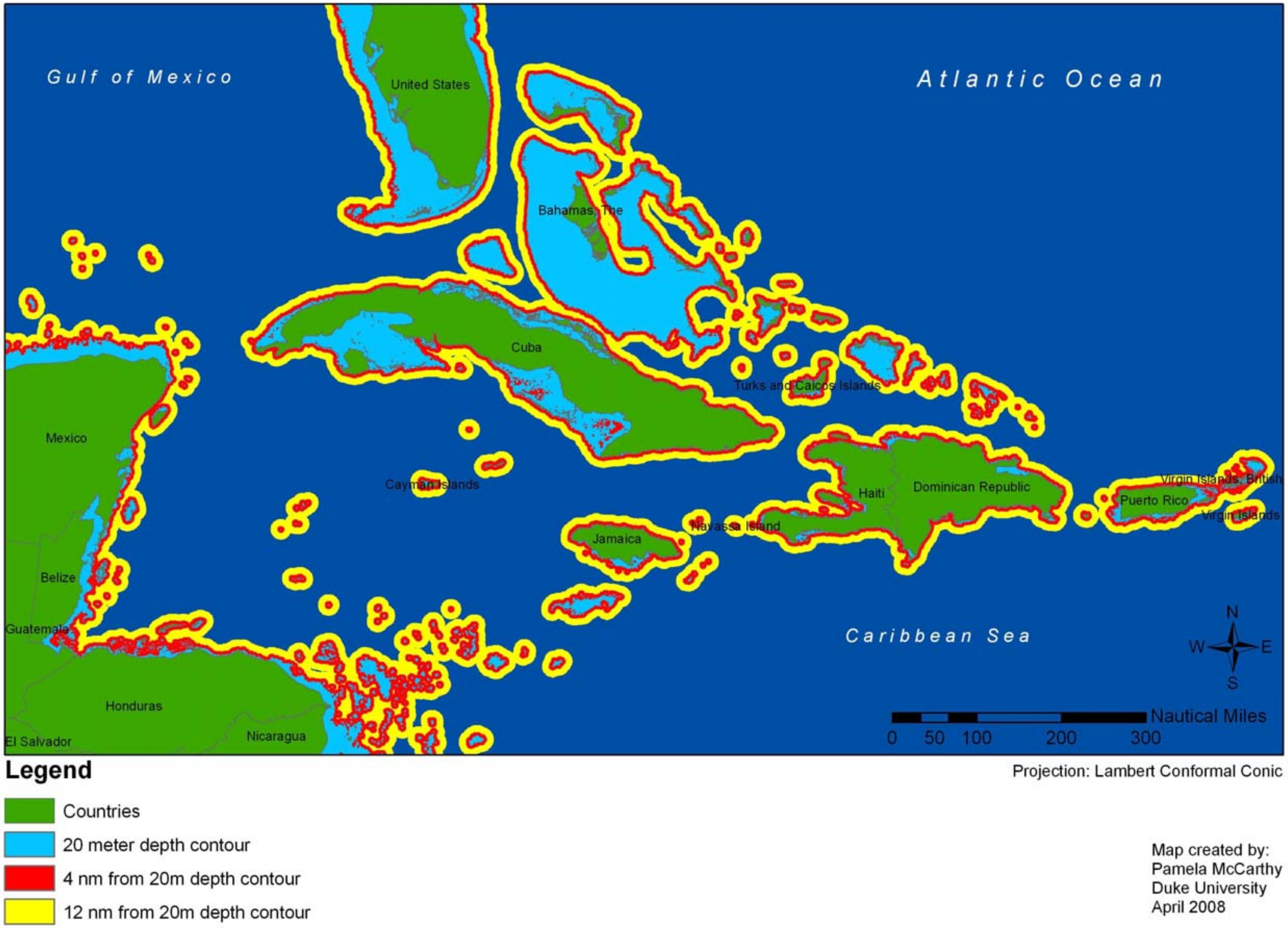
Projection: Lambert Conformal Conic

Created by:
Pamela McCarthy
Duke University
April 2008

Marine Protected Areas of the Caribbean Region
(4 nm and 12 nm from MPA locations)



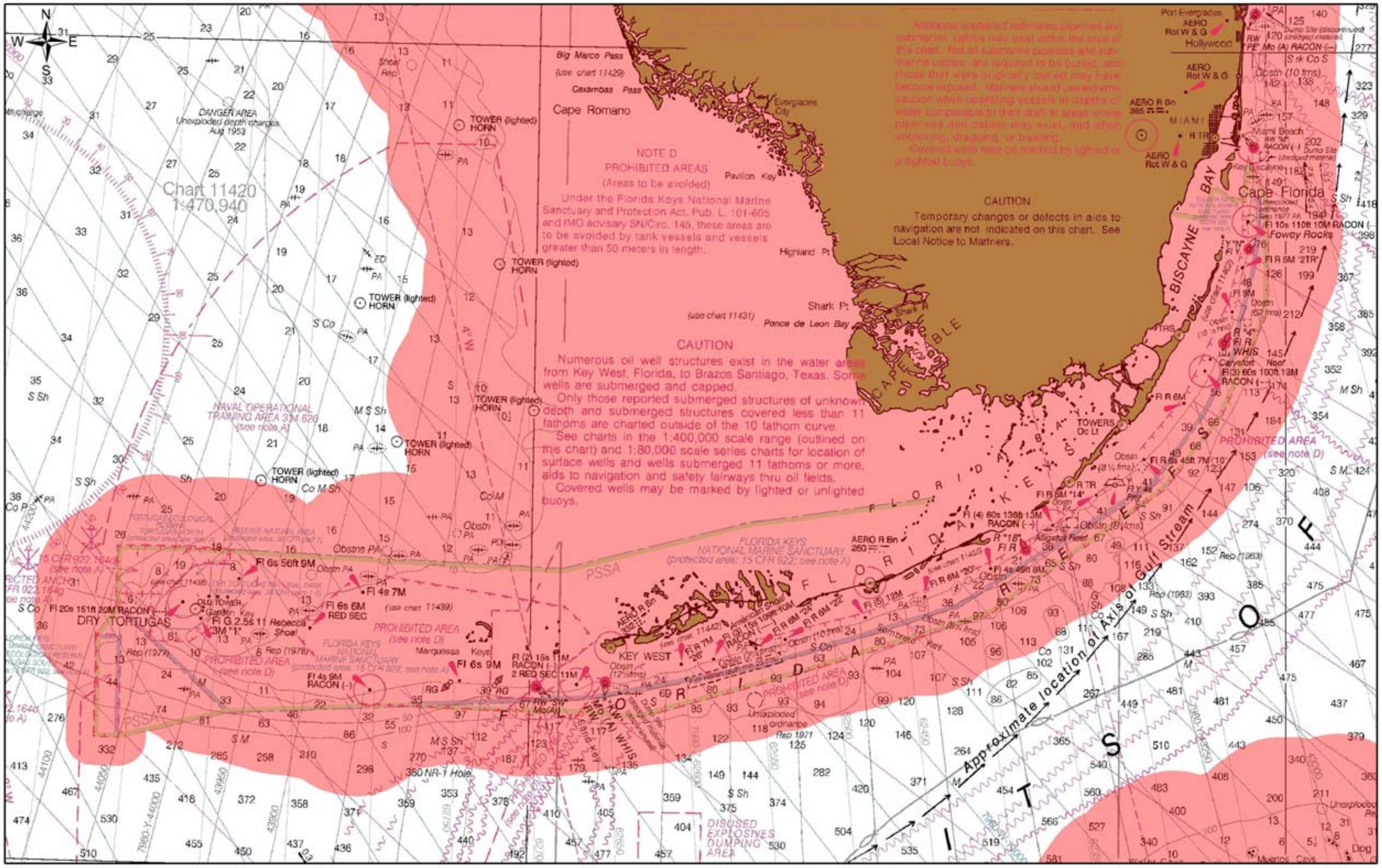
Bathymetry of the Caribbean Region
(4 nm and 12 nm from 20m depth contour)



Projection: Lambert Conformal Conic

Map created by:
Pamela McCarthy
Duke University
April 2008

Nautical Chart* of Discharges to be Avoided: Florida Keys



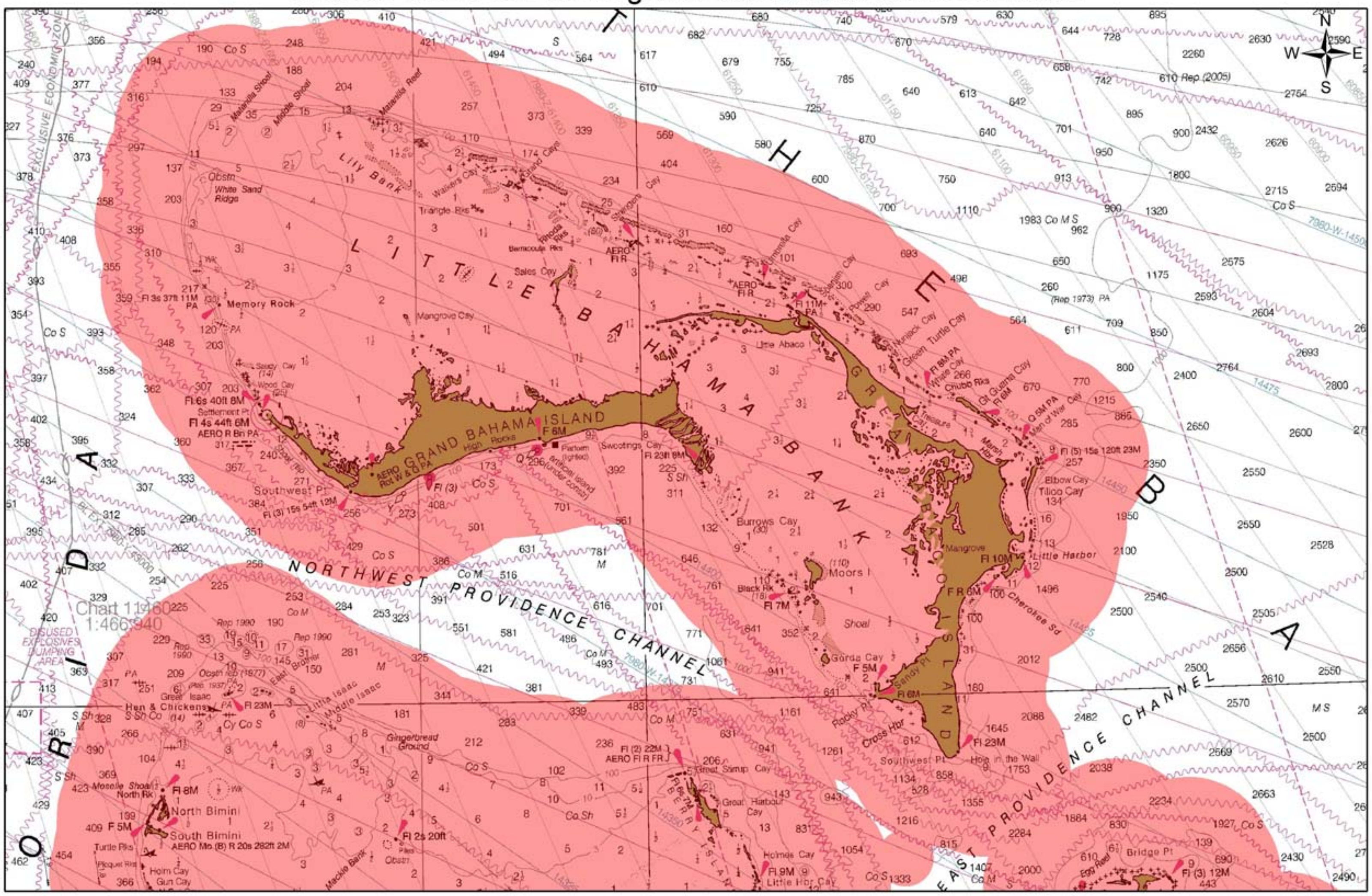
0 5 10 20 30 40 50 Nautical Miles

Discharge should be avoided in areas within 4nm of sensitive marine habitat and 12 nm of the 20m depth contour. Sensitive marine habitats include seamounts, shellfish beds, corals and coral reefs, mangroves, seagrasses, kelp beds, and marine protected areas (as defined by best available data to CI and Duke University).

Projection: Lambert Conformal Conic
*Not to be used for navigational purposes

Map prepared by:
Pamela McCarthy
Duke University
15 July 2007

Nautical Chart* of Discharges to be Avoided: North Bahamas



Discharge should be avoided in areas within 4nm of sensitive marine habitat and 12 nm of the 20m depth contour. Sensitive marine habitats include seamounts, shellfish beds, corals and coral reefs, mangroves, seagrasses, kelp beds, and marine protected areas (as defined by best available data to CI and Duke University).

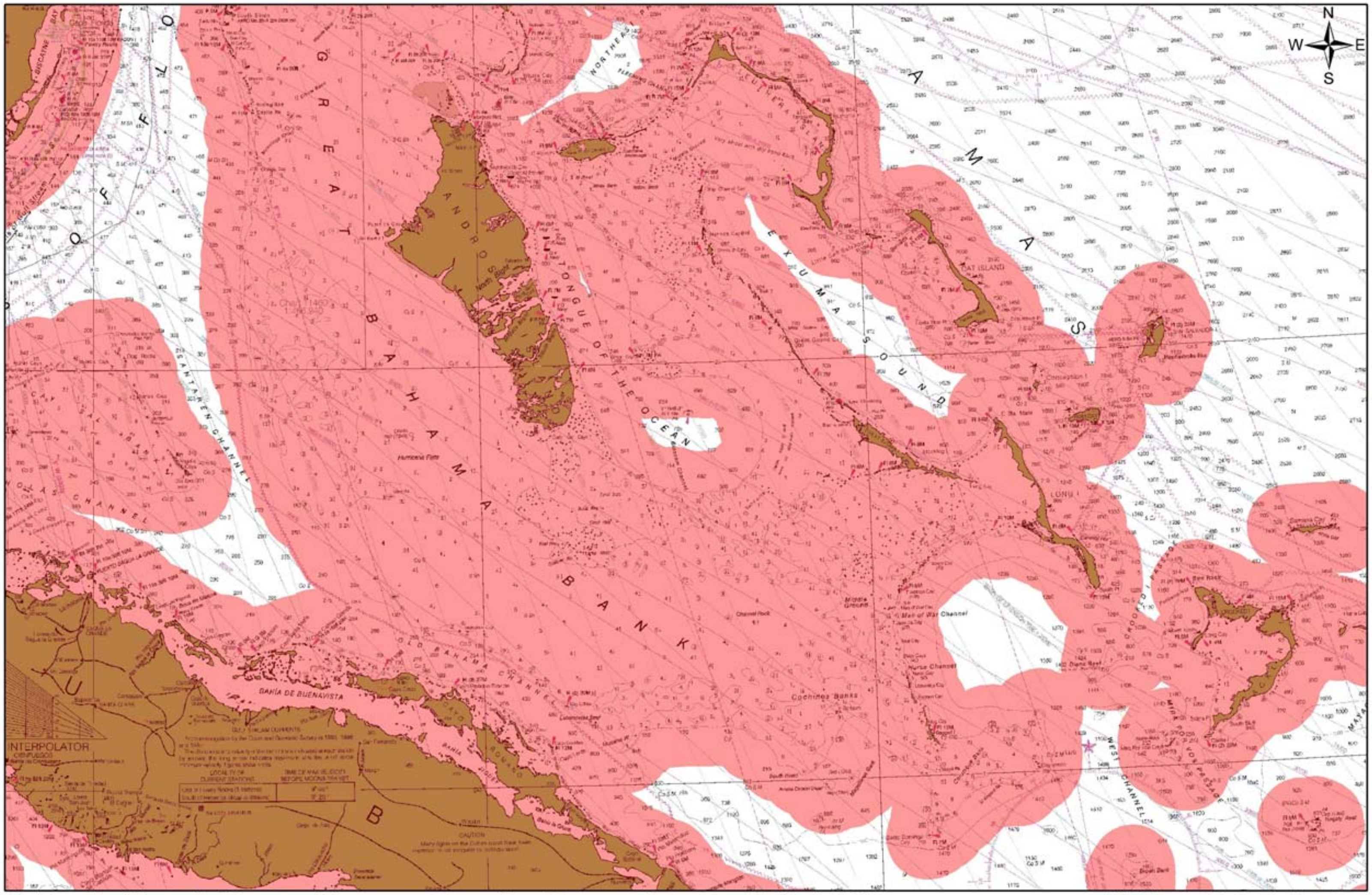
0 5 10 20 30 40 50 Nautical Miles

Projection: Lambert Conformal Conic

*Not intended for navigational use

Map prepared by:
Pamela McCarthy
Duke University
15 July 2007

Nautical Chart* of Discharges to be Avoided: South Bahamas



Discharge should be avoided in areas within 4nm of sensitive marine habitat and 12 nm of the 20m depth contour. Sensitive marine habitats include seamounts, shellfish beds, corals and coral reefs, mangroves, seagrasses, kelp beds, and marine protected areas (as defined by best available data to CI and Duke University).

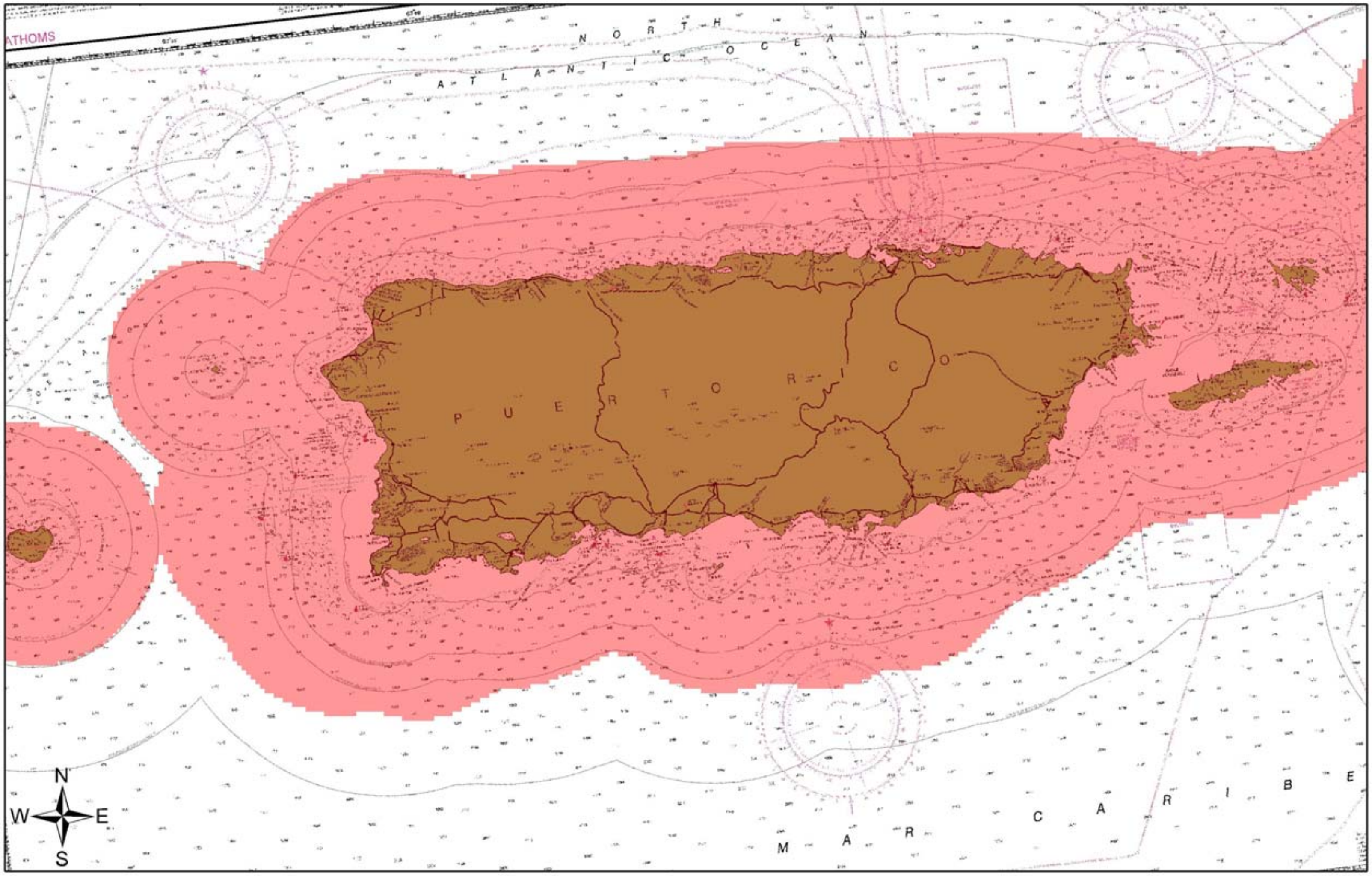
0 15 30 60 90 Nautical Miles

*Not intended for navigational use

Projection: Lambert Conformal Conic

Map prepared by:
Pamela McCarthy
Duke University
15 July 2007

Nautical Chart* of Discharge to be Avoided: Puerto Rico



0 5 10 20 30 40 50 Nautical Miles

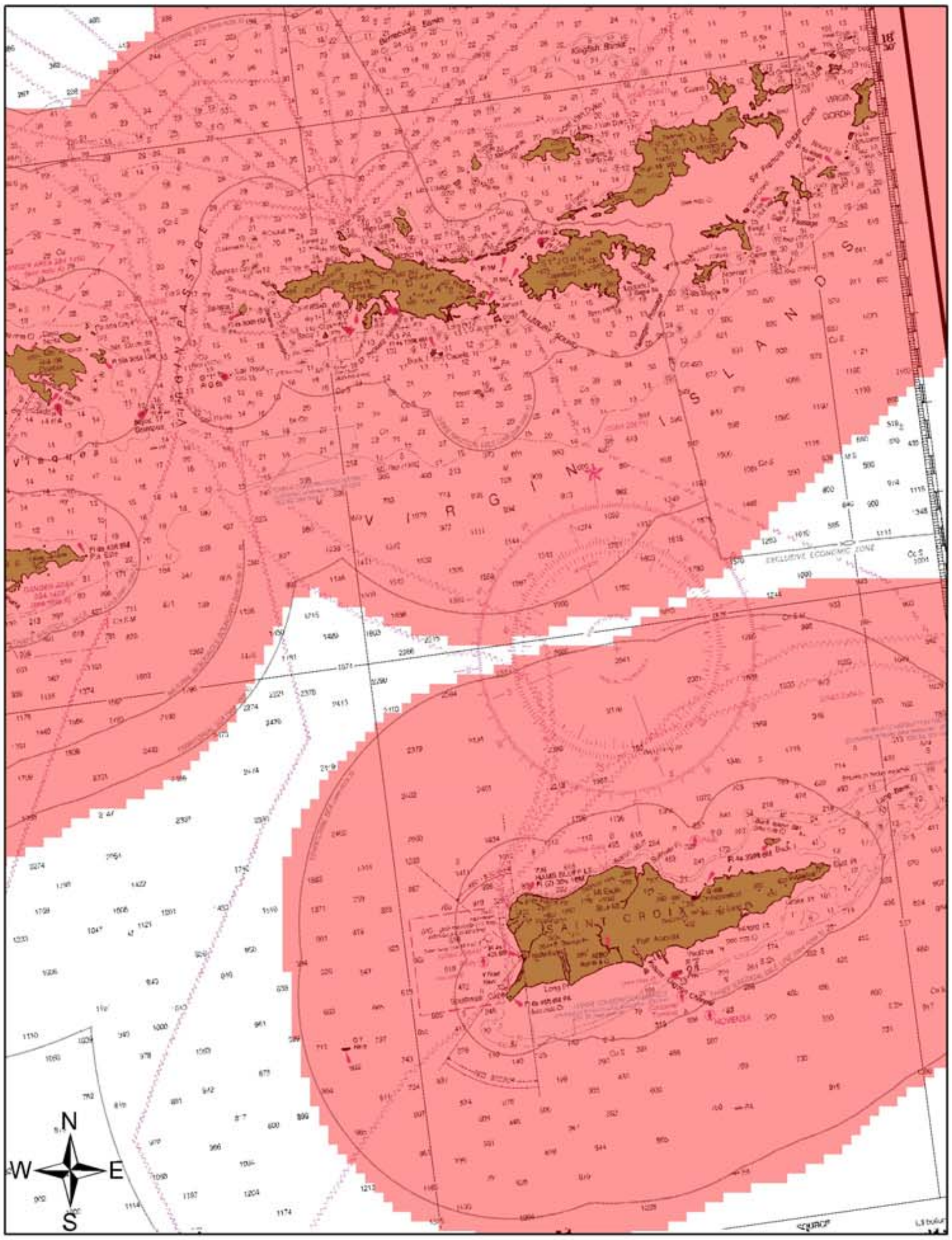
Discharge should be avoided in areas within 4nm of sensitive marine habitat and 12 nm of the 20m depth contour. Sensitive marine habitats include seamounts, shellfish beds, corals and coral reefs, mangroves, seagrasses, kelp beds, and marine protected areas (as defined by best available data to CI and Duke University).

*Not intended for navigational use

Projection: Lambert Conformal Conic

Map prepared by:
Pamela McCarthy
Duke University
15 July 2007

Nautical Chart* of Discharge to be Avoided: Virgin Islands



Discharge should be avoided in areas within 4nm of sensitive marine habitat and 12 nm of the 20m depth contour. Sensitive marine habitats include seamounts, shellfish beds, corals and coral reefs, mangroves, seagrasses, kelp beds, and marine protected areas (as defined by best available data to CI and Duke University).

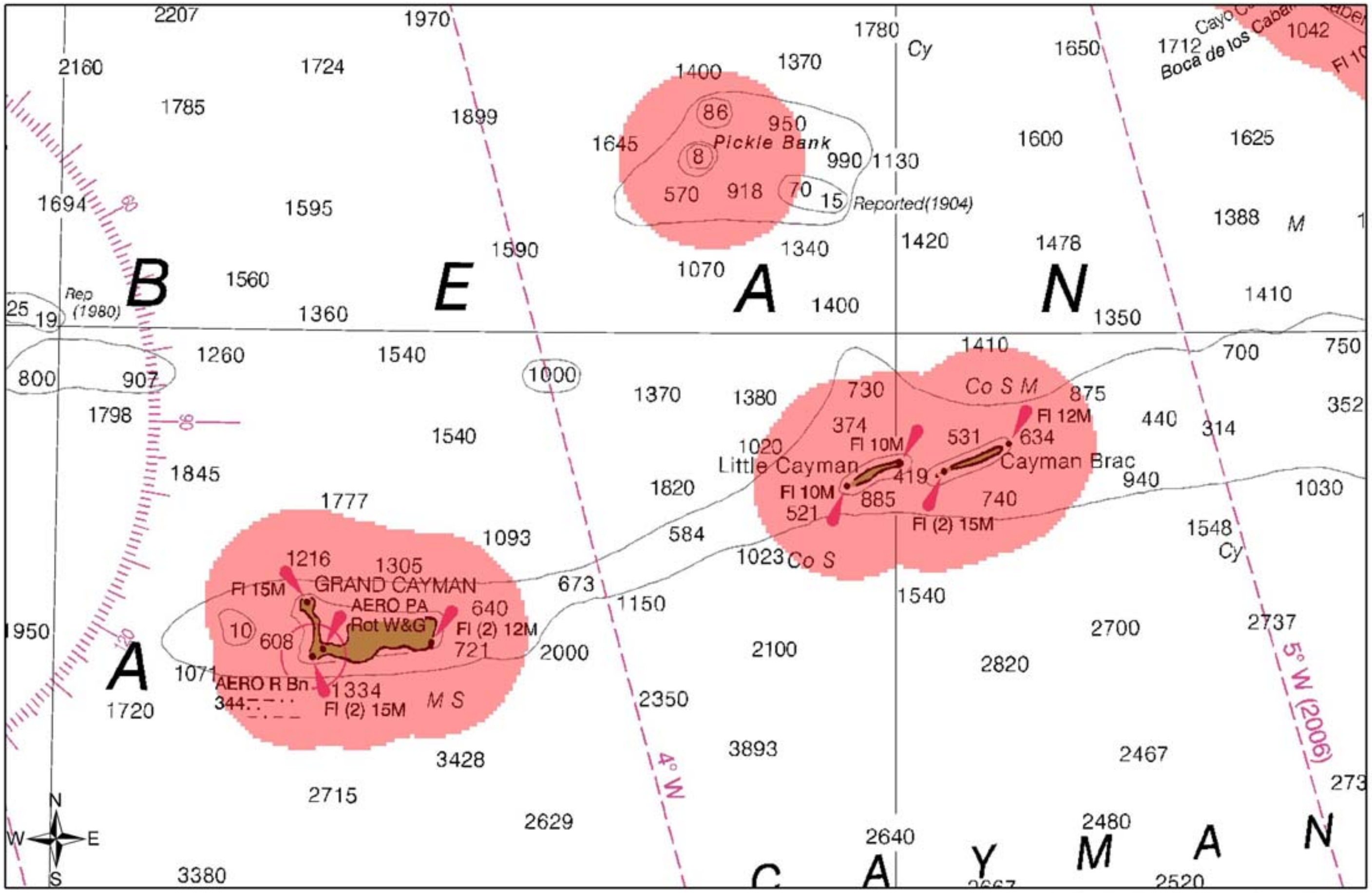
0 2 4 8 12 16 20 Nautical Miles

Projection: Lambert Conformal Conic

Map prepared by:
Pamela McCarthy
Duke University
15 July 2007

*Not intended for navigational use

Nautical Chart* of Discharges to be Avoided: Cayman Islands



Discharge should be avoided in areas within 4nm of sensitive marine habitat and 12 nm of the 20m depth contour. Sensitive marine habitats include seamounts, shellfish beds, corals and coral reefs, mangroves, seagrasses, kelp beds, and marine protected areas (as defined by best available data to CI and Duke University).

0 5 10 20 30 40 50 Nautical Miles

Projection: Lambert Conformal Conic

*Not intended for navigational use

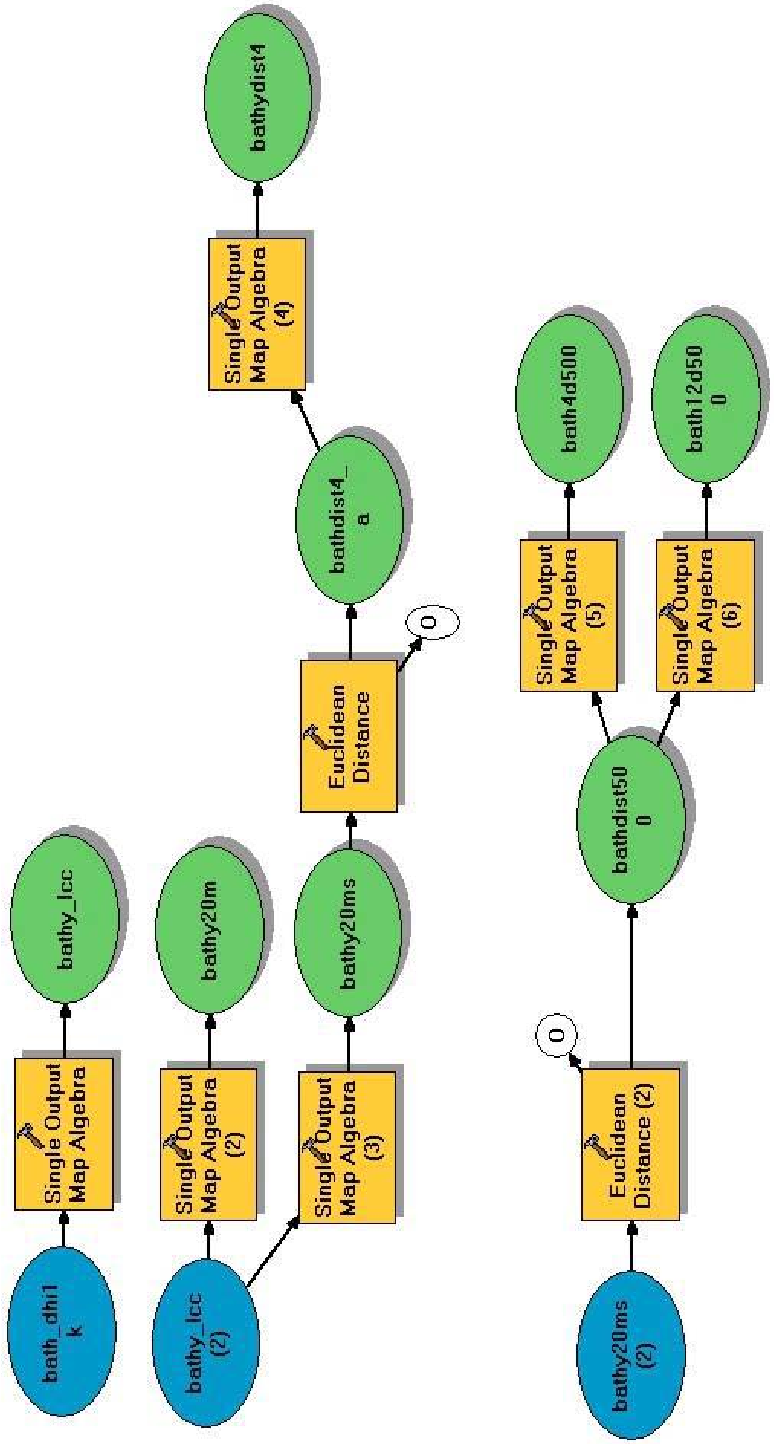
Map prepared by:
Pamela McCarthy
Duke University
15 July 2007

Appendix B

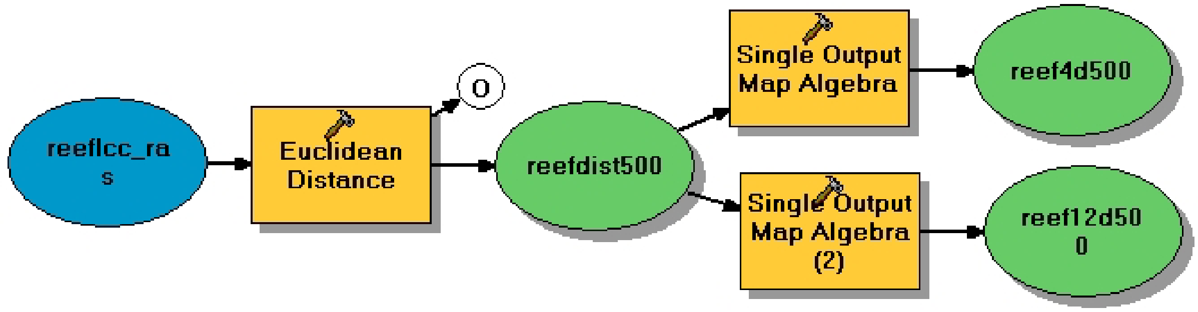
Models used for geospatial analyses

1. Bathymetry
2. Reefs
3. Marine Protected Areas
4. Distance calculation, part 1
5. Distance calculation, part 2

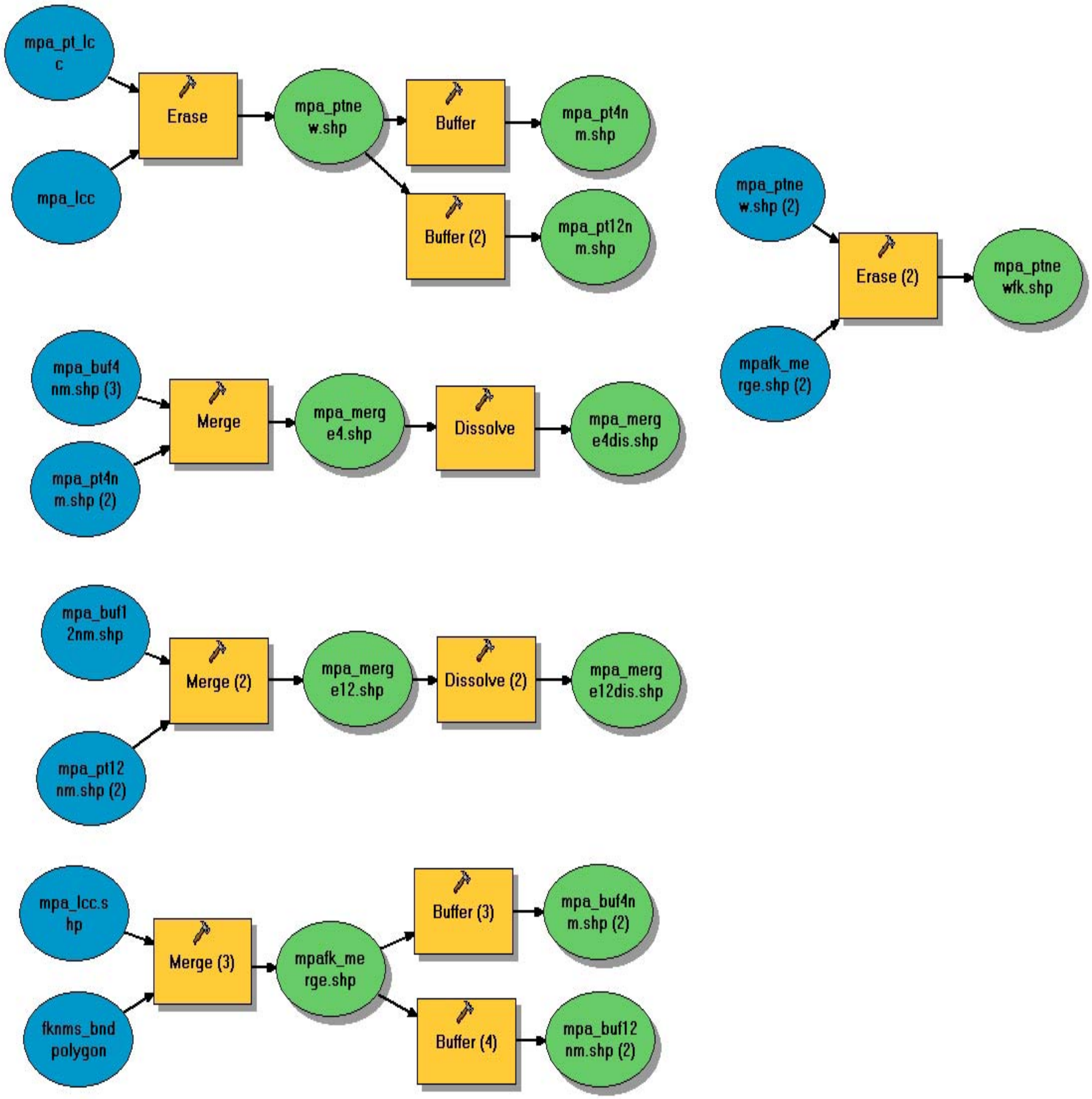
Bathymetry Model



Reef Model


reeflcc_ra
s
Euclidean
Distance
O
reefdist500
Single Output
Map Algebra
reef4d500
Single Output
Map Algebra
(2)
reef12d50
0

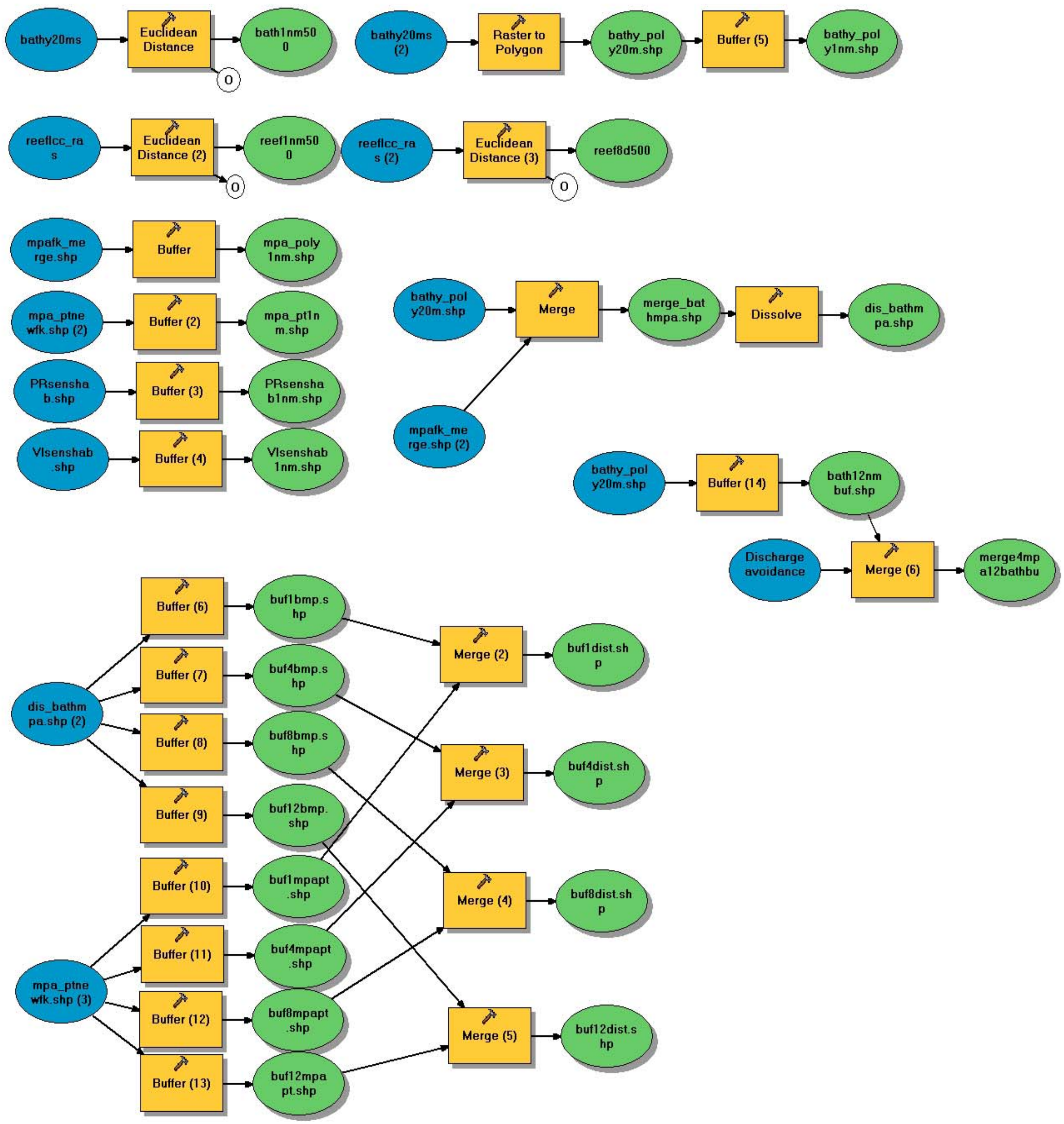
MPA Model



mpa_pt_lc
c
Erase
mpa_ptne
w.shp
Buffer
mpa_pt4n
m.shp
mpa_lcc
Buffer (2)
mpa_pt12n
m.shp
mpa_ptne
w.shp (2)
Erase (2)
mpa_ptne
wfk.shp
mpafk_me
rge.shp (2)
mpa_buf4
nm.shp (3)
Merge
mpa_merg
e4.shp
Dissolve
mpa_merg
e4dis.shp
mpa_pt4n
m.shp (2)
mpa_buf1
2nm.shp
Merge (2)
mpa_merg
e12.shp
Dissolve (2)
mpa_merg
e12dis.shp
mpa_pt12
nm.shp (2)
mpa_lcc.s
hp
Merge (3)
mpafk_me
rge.shp
Buffer (3)
mpa_buf4n
m.shp (2)
fknms_bnd
polygon
Buffer (4)
mpa_buf12
nm.shp (2)

Distance calculations, part 1

Distance calculation, part 2



Appendix C

Model Scripts

1. Bathymetry
2. Reefs
3. Marine Protected Areas
4. Distance calculation, part 1
5. Distance calculation, part 2

```
# ---------------------------------------------------------------------------
# Bathymetry.py
# Created on: Sun Apr 20 2008 07:27:56 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "I:\\Data_for_Pam_McCarthy\\Caribbean"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem =
"PROJCS['NAD_1983_Lambert_Conformal_Conic',GEOGCS['GCS_North_American_1983',D
ATUM['D_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PR
IMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Lambert_
Conformal_Conic'],PARAMETER['False_Easting',0.0],PARAMETER['False_Northing',0
.0],PARAMETER['Central_Meridian',-
80.0],PARAMETER['Standard_Parallel_1',26.0757777777778],PARAMETER['Standard_
Parallel_2',35.1088888888889],PARAMETER['Latitude_Of_Origin',30.592333333333
33],UNIT['Meter',1.0]]"
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "MAXOF"
gp.XYTolerance = ""
gp.cellSize = "1000"
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = ""
gp.workspace = "I:\\Data_for_Pam_McCarthy\\Caribbean"
gp.MResolution = ""
gp.ZTolerance = ""


# Local variables...
bath_dhi1k =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cy
l4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\
\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Car
ibbean\\RR_CARIB\\lambert\\bath_dhi1k"
bathy_lcc =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cy
l4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\
```

```
\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Car
ibbean\\bathy_lcc"
bathy20m =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cy
l4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\
\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Car
ibbean\\bathy20m"
bathy_lcc__2_ = "bathy_lcc"
bathy20ms =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\bathy20ms"
bathdist4_a =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\bathdist4_a"
Output_direction_raster = ""
bathydist4 =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\bathydist4"
bathdist500 =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\bathdist500"
Output_direction_raster__2_ = ""
bathy20ms__2_ = "bathy20ms"
bath4d500 =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\bath4d500"
bath12d500 =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\bath12d500"

# Process: Single Output Map Algebra...
gp.SingleOutputMapAlgebra_sa("I:\\Data_for_Pam_McCarthy\\Caribbean\\RR_CARIB\
\lambert\\bath_dhi1k * 1", bathy_lcc,
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cy
l4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\
\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Car
ibbean\\RR_CARIB\\lambert\\bath_dhi1k")

# Process: Single Output Map Algebra (2)...
gp.SingleOutputMapAlgebra_sa("con (
I:\\Data_for_Pam_McCarthy\\Caribbean\\bathy_lcc > -20, 1, 0)", bathy20m,
"bathy_lcc")

# Process: Single Output Map Algebra (3)...
gp.SingleOutputMapAlgebra_sa("con
(I:\\Data_for_Pam_McCarthy\\Caribbean\\bathy_lcc > -20, 1)", bathy20ms,
"bathy_lcc")

# Process: Euclidean Distance...
gp.EucDistance_sa(bathy20ms, bathdist4_a, "", "1000",
Output_direction_raster)

# Process: Single Output Map Algebra (4)...
gp.SingleOutputMapAlgebra_sa("con
(I:\\Data_for_Pam_McCarthy\\Caribbean\\bathdist4_a <= 7408, bathdist4_a)",
bathydist4,
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\bathdist4_a")

# Process: Euclidean Distance (2)...
```

```
gp.EucDistance_sa(bathy20ms__2_, bathdist500, "", "500",
Output_direction_raster__2_)

# Process: Single Output Map Algebra (5)...
gp.SingleOutputMapAlgebra_sa("con
(I:\\Data_for_Pam_McCarthy\\Caribbean\\bathdist500 <= 7408, bathdist500)
", bath4d500,
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\bathdist500")

# Process: Single Output Map Algebra (6)...
gp.SingleOutputMapAlgebra_sa("con
(I:\\Data_for_Pam_McCarthy\\Caribbean\\bathdist500 <= 22224, bathdist500)",
bath12d500,
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\bathdist500")


# ---------------------------------------------------------------------------
# Reefs.py
# Created on: Sun Apr 20 2008 07:28:35 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "I:\\Data_for_Pam_McCarthy\\Caribbean"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem =
"PROJCS['NAD_1983_Lambert_Conformal_Conic',GEOGCS['GCS_North_American_1983',D
ATUM['D_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PR
IMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Lambert_
Conformal_Conic'],PARAMETER['False_Easting',0.0],PARAMETER['False_Northing',0
.0],PARAMETER['Central_Meridian',-
80.0],PARAMETER['Standard_Parallel_1',26.07577777777778],PARAMETER['Standard_
Parallel_2',35.10888888888889],PARAMETER['Latitude_Of_Origin',30.592333333333
33],UNIT['Meter',1.0]]"
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "MAXOF"
gp.XYTolerance = ""
gp.cellSize = "500"
gp.outputZValue = ""
```

```
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = ""
gp.workspace = "I:\\Data_for_Pam_McCarthy\\Caribbean"
gp.MResolution = ""
gp.ZTolerance = ""


# Local variables...
reeflcc_ras = "reeflcc_ras"
reefdist500 =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\reefdist500"
Output_direction_raster = ""
reef4d500 =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\reef4d500"
reef12d500 =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\reef12d500"

# Process: Euclidean Distance...
gp.EucDistance_sa(reeflcc_ras, reefdist500, "", "500",
Output_direction_raster)

# Process: Single Output Map Algebra...
gp.SingleOutputMapAlgebra_sa("con
(I:\\Data_for_Pam_McCarthy\\Caribbean\\reefdist500 <= 7408, reefdist500)",
reef4d500,
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\reefdist500")

# Process: Single Output Map Algebra (2)...
gp.SingleOutputMapAlgebra_sa("con
(I:\\Data_for_Pam_McCarthy\\Caribbean\\reefdist500 <= 22224, reefdist500)
", reef12d500,
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\reefdist500")


# ---------------------------------------------------------------------------
# MPAs.py
# Created on: Sun Apr 20 2008 07:29:08 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Set the necessary product code
gp.SetProduct("ArcInfo")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management
Tools.tbx")
```

```
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis
Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "I:\\Data_for_Pam_McCarthy\\Caribbean"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem =
"PROJCS['NAD_1983_Lambert_Conformal_Conic',GEOGCS['GCS_North_American_1983',D
ATUM['D_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PR
IMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Lambert_
Conformal_Conic'],PARAMETER['False_Easting',0.0],PARAMETER['False_Northing',0
.0],PARAMETER['Central_Meridian',-
80.0],PARAMETER['Standard_Parallel_1',26.07577777777778],PARAMETER['Standard_
Parallel_2',35.10888888888889],PARAMETER['Latitude_Of_Origin',30.592333333333
33],UNIT['Meter',1.0]]"
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "I:\\Data_for_Pam_McCarthy\\Caribbean"
gp.MResolution = ""
gp.ZTolerance = ""


# Local variables...
mpa_ptnew_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_ptnew.shp"
mpa_pt_lcc = "mpa_pt_lcc"
mpa_lcc = "mpa_lcc"
mpa_pt4nm_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_pt4nm.shp"
mpa_pt12nm_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_pt12nm.shp"
mpa_merge4_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_merge4.shp"
mpa_pt4nm_shp__2_ = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_pt4nm.shp"
mpa_merge12_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_merge12.shp"
mpa_pt12nm_shp__2_ = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_pt12nm.shp"
mpafk_merge_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp"
mpa_lcc_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_lcc.shp"
fknms_bnd_polygon =
"I:\\Data_for_Pam_McCarthy\\Fla_keys9_1\\fknms_bnd\\polygon"
mpa_buf4nm_shp__2_ = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_buf4nm.shp"
mpa_buf12nm_shp__2_ = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_buf12nm.shp"
mpa_buf4nm_shp__3_ = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_buf4nm.shp"
mpa_buf12nm_shp__3_ = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_buf12nm.shp"
mpa_merge4dis_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_merge4dis.shp"
mpa_merge12dis_shp =
"I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_merge12dis.shp"
mpa_ptnewfk_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_ptnewfk.shp"
mpa_ptnew_shp__2_ = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_ptnew.shp"
mpafk_merge_shp__2_ = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp"

# Process: Erase...
gp.Erase_analysis(mpa_pt_lcc, mpa_lcc, mpa_ptnew_shp, "")
```

```
# Process: Buffer...
gp.Buffer_analysis(mpa_ptnew_shp, mpa_pt4nm_shp, "7408 Meters", "FULL",
"ROUND", "ALL", "")

# Process: Buffer (2)...
gp.Buffer_analysis(mpa_ptnew_shp, mpa_pt12nm_shp, "22224 Meters", "FULL",
"ROUND", "ALL", "")

# Process: Merge (3)...
gp.Merge_management("I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_lcc.shp;I:\\Da
ta_for_Pam_McCarthy\\Fla_keys9_1\\fknms_bnd\\polygon", mpafk_merge_shp,
"MPA_ID MPA_ID true false false 4 Short 0 4
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_lcc.shp,MPA_ID,-1,-
1;MPA_NAME MPA_NAME true false false 34 Text 0 0
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_lcc.shp,MPA_NAME,-1,-
1;POLY_SOURC POLY_SOURC true false false 19 Text 0 0
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_lcc.shp,POLY_SOURC,-1,-
1;FINAL_LEVE FINAL_LEVE true false false 12 Text 0 0
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_lcc.shp,FINAL_LEVE,-1,-
1;AREA AREA false false true 4 Float 0 0
,First,#,I:\\Data_for_Pam_McCarthy\\Fla_keys9_1\\fknms_bnd\\polygon,AREA,-1,-
1;PERIMETER PERIMETER false false true 4 Float 0 0
,First,#,I:\\Data_for_Pam_McCarthy\\Fla_keys9_1\\fknms_bnd\\polygon,PERIMETER
,-1,-1;FKNMS_BND_ FKNMS_BND_ false false true 4 Long 0 0
,First,#,I:\\Data_for_Pam_McCarthy\\Fla_keys9_1\\fknms_bnd\\polygon,FKNMS_BND
#,-1,-1;FKNMS_BND1 FKNMS_BND1 true false true 4 Long 0 0
,First,#,I:\\Data_for_Pam_McCarthy\\Fla_keys9_1\\fknms_bnd\\polygon,FKNMS_BND
-ID,-1,-1;DESCRIP DESCRIP true false false 30 Text 0 0
,First,#,I:\\Data_for_Pam_McCarthy\\Fla_keys9_1\\fknms_bnd\\polygon,DESCRIP,-
1,-1")

# Process: Buffer (3)...
gp.Buffer_analysis(mpafk_merge_shp, mpa_buf4nm_shp__2_, "7408 Meters",
"FULL", "ROUND", "ALL", "")

# Process: Buffer (4)...
gp.Buffer_analysis(mpafk_merge_shp, mpa_buf12nm_shp__2_, "22224 Meters",
"FULL", "ROUND", "ALL", "")

# Process: Merge...
gp.Merge_management("I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_pt4nm.shp;I:\\
Data_for_Pam_McCarthy\\Caribbean\\mpa_buf4nm.shp", mpa_merge4_shp, "Id Id
true false false 6 Long 0 6
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_pt4nm.shp,Id,-1,-
1,I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_buf4nm.shp,Id,-1,-1")

# Process: Dissolve...
gp.Dissolve_management(mpa_merge4_shp, mpa_merge4dis_shp, "Id", "",
"SINGLE_PART")

# Process: Merge (2)...
gp.Merge_management("I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_pt12nm.shp;I:\
\Data_for_Pam_McCarthy\\Caribbean\\mpa_buf12nm.shp", mpa_merge12_shp, "Id Id
true false false 6 Long 0 6
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_pt12nm.shp,Id,-1,-
1,I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_buf12nm.shp,Id,-1,-1")
```

```
# Process: Dissolve (2)...
gp.Dissolve_management(mpa_merge12_shp, mpa_merge12dis_shp, "Id", "",
"SINGLE_PART")

# Process: Erase (2)...
gp.Erase_analysis(mpa_ptnew_shp__2_, mpafk_merge_shp__2_, mpa_ptnewfk_shp,
"")


# ---------------------------------------------------------------------------
# Distances1.py
# Created on: Sun Apr 20 2008 07:29:39 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion
Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "I:\\Data_for_Pam_McCarthy\\Caribbean"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem = ""
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "DEFAULT"
gp.XYTolerance = ""
gp.cellSize = "1000"
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.mask = ""
gp.workspace = "I:\\Data_for_Pam_McCarthy\\Caribbean"
gp.MResolution = ""
gp.ZTolerance = ""


# Local variables...
bathy_20m =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\bathy_20m"
bath_dhi1k = "bath_dhi1k"
```

```
reef_dist4nm =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\reef_dist4nm"
Output_direction_raster__2_ = ""
reef_500 = "reef_500"
reef_dist1nm =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\reef_dist1nm"
Output_direction_raster = ""
reef_dist12nm =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\reef_dist12nm"
Output_direction_raster__3_ = ""
reef_dist20nm =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\reef_dist20nm"
Output_direction_raster__4_ = ""
mpa_lcc = "mpa_lcc"
mpalcc_ras =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cy
l4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\
\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Car
ibbean\\mpalcc_ras"
mpa_dist1nm =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\mpa_dist1nm"
Output_direction_raster__5_ = ""
mpa_dist4nm =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\mpa_dist4nm"
Output_direction_raster__6_ = ""
mpa_dist12nm =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\mpa_dist12nm"
Output_direction_raster__7_ = ""
mpa_dist20nm =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\mpa_dist20nm"
Output_direction_raster__8_ = ""
reeflcc_ras = "reeflcc_ras"
reefdist_1nm =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\reefdist_1nm"
Output_direction_raster__9_ = ""
reefdist_4nm =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\reefdist_4nm"
Output_direction_raster__10_ = ""
reefdist_12nm =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\reefdist_12nm"
Output_direction_raster__11_ = ""
reefdist_20nm =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\reefdist_20nm"
Output_direction_raster__12_ = ""

# Process: Con...
gp.Con_sa(bath_dhi1k, bath_dhi1k, bathy_20m, "", "\"VALUE\" <= -20")

# Process: Euclidean Distance (2)...
```

```
gp.EucDistance_sa(reef_500, reef_dist4nm, "7408", "500",
Output_direction_raster__2_)

# Process: Euclidean Distance...
gp.EucDistance_sa(reef_500, reef_dist1nm, "1852", "500",
Output_direction_raster)

# Process: Euclidean Distance (3)...
gp.EucDistance_sa(reef_500, reef_dist12nm, "22224", "500",
Output_direction_raster__3_)

# Process: Euclidean Distance (4)...
gp.EucDistance_sa(reef_500, reef_dist20nm, "37040", "500",
Output_direction_raster__4_)

# Process: Feature to Raster...
gp.FeatureToRaster_conversion(mpa_lcc, "MPA_NAME", mpalcc_ras, "1000")

# Process: Euclidean Distance (5)...
gp.EucDistance_sa(mpalcc_ras, mpa_dist1nm, "1852", "1000",
Output_direction_raster__5_)

# Process: Euclidean Distance (6)...
gp.EucDistance_sa(mpalcc_ras, mpa_dist4nm, "7408", "1000",
Output_direction_raster__6_)

# Process: Euclidean Distance (7)...
gp.EucDistance_sa(mpalcc_ras, mpa_dist12nm, "22224", "1000",
Output_direction_raster__7_)

# Process: Euclidean Distance (8)...
gp.EucDistance_sa(mpalcc_ras, mpa_dist20nm, "37040", "1000",
Output_direction_raster__8_)

# Process: Euclidean Distance (9)...
gp.EucDistance_sa(reeflcc_ras, reefdist_1nm, "1852", "1000",
Output_direction_raster__9_)

# Process: Euclidean Distance (10)...
gp.EucDistance_sa(reeflcc_ras, reefdist_4nm, "7408", "1000",
Output_direction_raster__10_)

# Process: Euclidean Distance (11)...
gp.EucDistance_sa(reeflcc_ras, reefdist_12nm, "22224", "1000",
Output_direction_raster__11_)

# Process: Euclidean Distance (12)...
gp.EucDistance_sa(reeflcc_ras, reefdist_20nm, "37040", "1000",
Output_direction_raster__12_)


# ---------------------------------------------------------------------------
# Distances2.py
# Created on: Sun Apr 20 2008 07:26:59 PM
#   (generated by ArcGIS/ModelBuilder)
# ---------------------------------------------------------------------------
```

```
# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Conversion
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Data Management
Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysis
Tools.tbx")

# Set the Geoprocessing environment...
gp.XYResolution = ""
gp.scratchWorkspace = "I:\\d0oafo~2\\cyl4q8~e"
gp.MTolerance = ""
gp.randomGenerator = "0 ACM599"
gp.outputCoordinateSystem =
"PROJCS['NAD_1983_Lambert_Conformal_Conic',GEOGCS['GCS_North_American_1983',D
ATUM['D_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PR
IMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Lambert_
Conformal_Conic'],PARAMETER['False_Easting',0.0],PARAMETER['False_Northing',0
.0],PARAMETER['Central_Meridian',-
80.0],PARAMETER['Standard_Parallel_1',26.07577777777778],PARAMETER['Standard_
Parallel_2',35.10888888888889],PARAMETER['Latitude_Of_Origin',30.592333333333
33],UNIT['Meter',1.0]]"
gp.outputZFlag = "Same As Input"
gp.qualifiedFieldNames = "true"
gp.extent = "MAXOF"
gp.XYTolerance = ""
gp.outputZValue = ""
gp.outputMFlag = "Same As Input"
gp.geographicTransformations = ""
gp.ZResolution = ""
gp.workspace = "I:\\d0oafo~2\\cyl4q8~e"
gp.MResolution = ""
gp.ZTolerance = ""


# Local variables...
bath1nm500 =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\bath1nm500"
Output_direction_raster = ""
bathy20ms =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\bathy20ms"
reef1nm500 =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\reef1nm500"
```

```
Output_direction_raster__2_ = ""
reeflcc_ras =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\reeflcc_ras"
mpa_poly1nm_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\mpa_poly1nm.shp"
mpa_ptnewfk_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_ptnewfk.shp"
mpa_pt1nm_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\mpa_pt1nm.shp"
mpa_ptnewfk_shp__2_ =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\mpa_ptnewfk.shp"
mpafk_merge_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\mpafk_merge.shp"
PRsenshab1nm_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\additional_data\\NOS\\PR\\PRsens
hab1nm.shp"
PRsenshab_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\additional_data\\NOS\\PR\\PRsens
hab.shp"
VIsenshab1nm_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\additional_data\\NOS\\USVI\\VIse
nshab1nm.shp"
VIsenshab_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\additional_data\\NOS\\USVI\\VIse
nshab.shp"
bathy_poly20m_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cy
l4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\bathy_poly20m.shp"
bathy20ms__2_ =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\bathy20ms"
bathy_poly1nm_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\bathy_poly1nm.shp"
merge_bathmpa_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\merge_bathmpa.shp"
bathy_poly20m_shp__2_ =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\bathy_poly20m.shp"
mpafk_merge_shp__2_ =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp"
dis_bathmpa_shp =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\dis_bathmpa.shp"
buf1bmp_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\buf1bmp.shp"
dis_bathmpa_shp__2_ =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cy
l4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\dis_bathmpa.shp"
buf4bmp_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\buf4bmp.shp"
```

```
buf8bmp_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\buf8bmp.shp"
buf12bmp_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\buf12bmp.shp"
buf1mpapt_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\buf1mpapt.shp"
mpa_ptnewfk_shp__3_ =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cy
l4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpa_ptnewfk.shp"
buf4mpapt_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\buf4mpapt.shp"
buf8mpapt_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\buf8mpapt.shp"
buf12mpapt_shp =
"I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\buf12mpapt.shp"
buf1dist_shp =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\buf1dist.shp"
buf4dist_shp =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\buf4dist.shp"
buf8dist_shp =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\buf8dist.shp"
buf12dist_shp =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\buf12dist.shp"
reef8d500 =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\reef8d500"
Output_direction_raster__3_ = ""
reeflcc_ras__2_ =
"I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\reeflcc_ras"
bath12nmbuf_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\bath12nmbuf.shp"
bathy_poly20m_shp__3_ =
"I:\\Data_for_Pam_McCarthy\\Caribbean\\bathy_poly20m.shp"
merge4mpa12bathbuf_shp =
"I:\\Data_for_Pam_McCarthy\\Caribbean\\merge4mpa12bathbuf.shp"
mpa_merge4_shp = "I:\\Data_for_Pam_McCarthy\\Caribbean\\mpa_merge4.shp"
Discharge_avoidance_areas = "Discharge avoidance areas"

# Process: Euclidean Distance...
gp.EucDistance_sa(bathy20ms, bath1nm500, "1852", "500",
Output_direction_raster)

# Process: Euclidean Distance (2)...
gp.EucDistance_sa(reeflcc_ras, reef1nm500, "1852", "500",
Output_direction_raster__2_)

# Process: Buffer...
gp.Buffer_analysis(mpafk_merge_shp, mpa_poly1nm_shp, "1852 Meters", "FULL",
"ROUND", "NONE", "")

# Process: Buffer (2)...
gp.Buffer_analysis(mpa_ptnewfk_shp__2_, mpa_pt1nm_shp, "1852 Meters", "FULL",
"ROUND", "NONE", "")
```

```
# Process: Buffer (3)...
gp.Buffer_analysis(PRsenshab_shp, PRsenshab1nm_shp, "1852 Meters", "FULL",
"ROUND", "NONE", "")

# Process: Buffer (4)...
gp.Buffer_analysis(VIsenshab_shp, VIsenshab1nm_shp, "1852 Meters", "FULL",
"ROUND", "NONE", "")

# Process: Raster to Polygon...
gp.RasterToPolygon_conversion(bathy20ms__2_, bathy_poly20m_shp, "SIMPLIFY",
"VALUE")

# Process: Buffer (5)...
gp.Buffer_analysis(bathy_poly20m_shp, bathy_poly1nm_shp, "1852 Meters",
"FULL", "ROUND", "NONE", "")

# Process: Merge...
gp.Merge_management("I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean
\\bathy_poly20m.shp;I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\
\mpafk_merge.shp", merge_bathmpa_shp, "ID ID true false false 10 Double 0 10
,First,#,I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\bathy_poly
20m.shp,ID,-1,-1;GRIDCODE GRIDCODE true false false 10 Double 0 10
,First,#,I:\\d0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\bathy_poly
20m.shp,GRIDCODE,-1,-1;MPA_ID MPA_ID true false false 4 Short 0 4
,First,#,I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oa
fo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d
0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp,MPA_ID,-
1,-1;MPA_NAME MPA_NAME true false false 34 Text 0 0
,First,#,I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oa
fo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d
0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp,MPA_NAME
,-1,-1;POLY_SOURC POLY_SOURC true false false 19 Text 0 0
,First,#,I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oa
fo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d
0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp,POLY_SOU
RC,-1,-1;FINAL_LEVE FINAL_LEVE true false false 12 Text 0 0
,First,#,I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oa
fo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d
0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp,FINAL_LE
VE,-1,-1;AREA AREA true false false 13 Float 0 0
,First,#,I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oa
fo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d
0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp,AREA,-
1,-1;PERIMETER PERIMETER true false false 13 Float 0 0
,First,#,I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oa
fo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d
0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp,PERIMETE
R,-1,-1;FKNMS_BND_ FKNMS_BND_ true false false 9 Long 0 9
,First,#,I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oa
fo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d
0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp,FKNMS_BN
D_,-1,-1;FKNMS_BND1 FKNMS_BND1 true false false 9 Long 0 9
,First,#,I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oa
fo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d
0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp,FKNMS_BN
D1,-1,-1;DESCRIP DESCRIP true false false 30 Text 0 0
```

```
,First,#,I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oa
fo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\d
0oafo~2\\cyl4q8~e\\Data_for_Pam_McCarthy\\Caribbean\\mpafk_merge.shp,DESCRIP,
-1,-1")

# Process: Dissolve...
gp.Dissolve_management(merge_bathmpa_shp, dis_bathmpa_shp, "", "",
"SINGLE_PART")

# Process: Buffer (6)...
gp.Buffer_analysis(dis_bathmpa_shp__2_, buf1bmp_shp, "1852 Meters", "FULL",
"ROUND", "ALL", "")

# Process: Buffer (10)...
gp.Buffer_analysis(mpa_ptnewfk_shp__3_, buf1mpapt_shp, "1852 Meters", "FULL",
"ROUND", "ALL", "")

# Process: Merge (2)...
gp.Merge_management("I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\buf1bmp.shp;I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\
\Data_for_Pam_McCarthy\\Caribbean\\buf1mpapt.shp", buf1dist_shp, "Id Id true
false false 6 Long 0 6
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\buf1bmp.shp,Id,-1,-
1,I:\\Data_for_Pam_McCarthy\\Caribbean\\buf1mpapt.shp,Id,-1,-1")

# Process: Buffer (7)...
gp.Buffer_analysis(dis_bathmpa_shp__2_, buf4bmp_shp, "7408 Meters", "FULL",
"ROUND", "ALL", "")

# Process: Buffer (11)...
gp.Buffer_analysis(mpa_ptnewfk_shp__3_, buf4mpapt_shp, "7408 Meters", "FULL",
"ROUND", "ALL", "")

# Process: Merge (3)...
gp.Merge_management("I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\buf4bmp.shp;I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\
\Data_for_Pam_McCarthy\\Caribbean\\buf4mpapt.shp", buf4dist_shp, "Id Id true
false false 6 Long 0 6
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\buf4bmp.shp,Id,-1,-
1,I:\\Data_for_Pam_McCarthy\\Caribbean\\buf4mpapt.shp,Id,-1,-1")

# Process: Buffer (8)...
gp.Buffer_analysis(dis_bathmpa_shp__2_, buf8bmp_shp, "14816 Meters", "FULL",
"ROUND", "ALL", "")

# Process: Buffer (12)...
gp.Buffer_analysis(mpa_ptnewfk_shp__3_, buf8mpapt_shp, "14816 Meters",
"FULL", "ROUND", "ALL", "")

# Process: Merge (4)...
gp.Merge_management("I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\buf8bmp.shp;I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\
\Data_for_Pam_McCarthy\\Caribbean\\buf8mpapt.shp", buf8dist_shp, "Id Id true
false false 6 Long 0 6
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\buf8bmp.shp,Id,-1,-
1,I:\\Data_for_Pam_McCarthy\\Caribbean\\buf8mpapt.shp,Id,-1,-1")
```

```
# Process: Buffer (9)...
gp.Buffer_analysis(dis_bathmpa_shp__2_, buf12bmp_shp, "22224 Meters", "FULL",
"ROUND", "ALL", "")

# Process: Buffer (13)...
gp.Buffer_analysis(mpa_ptnewfk_shp__3_, buf12mpapt_shp, "22224 Meters",
"FULL", "ROUND", "ALL", "")

# Process: Merge (5)...
gp.Merge_management("I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e\\Data_for_Pam
_McCarthy\\Caribbean\\buf12bmp.shp;I:\\d0oafo~2\\cyl4q8~e\\d0oafo~2\\cyl4q8~e
\\Data_for_Pam_McCarthy\\Caribbean\\buf12mpapt.shp", buf12dist_shp, "Id Id
true false false 6 Long 0 6
,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\buf12bmp.shp,Id,-1,-
1,I:\\Data_for_Pam_McCarthy\\Caribbean\\buf12mpapt.shp,Id,-1,-1")

# Process: Euclidean Distance (3)...
gp.EucDistance_sa(reeflcc_ras__2_, reef8d500, "14816", "500",
Output_direction_raster__3_)

# Process: Buffer (14)...
gp.Buffer_analysis(bathy_poly20m_shp__3_, bath12nmbuf_shp, "22224 Meters",
"FULL", "ROUND", "ALL", "")

# Process: Merge (6)...
gp.Merge_management("I:\\Data_for_Pam_McCarthy\\Caribbean\\bath12nmbuf.shp;'D
ischarge avoidance areas'", merge4mpa12bathbuf_shp, "Id Id true false false 6
Long 0 6 ,First,#,I:\\Data_for_Pam_McCarthy\\Caribbean\\bath12nmbuf.shp,Id,-
1,-1,Discharge avoidance areas,Id,-1,-1")
```