AN INTRA-AMERICAS SEA TSUNAMI WARNING SYSTEM
PROJECT PROPOSAL

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EXECUTIVE SUMMARY

Tsunamis are among the world's most destructive coastal hazards. They occur in all the world's oceans, inland seas, and many other large bodies of waters. Scientists have provided a record of past tsunamis that clearly indicates the potential for future tsunami damage within the Intra-Americas Sea and they have warned governments to take urgent action. The sharp increase in coastal population density, the intense development of harbours and urban infrastructure, and the exploitation of mineral resources in coastal areas, all set up a potential disaster of catastrophic proportions.

This proposal is for a 3-year programme to develop a tsunami warning system for the Intra-Americas Sea with the ultimate goal to save lives and property. It is based on an end-to-end principle – from data collection to the provision of services and issuing warnings. It includes efforts in developing data collection sites, communication arrangements, development of tsunami warning centres (national as well as regional), distribution of information, and raising the level of tsunami education and awareness. The proposal considers the ways of contributing to earthquake and tsunami research, and to capacity building and human resources development through creating educational programmes and organizing workshops and conferences.

The proposal is based on the experience gained by the IOC Member States of the Pacific in operating the Tsunami Warning System in the Pacific and the collective wisdom of scientists, engineers, managers and citizens. It is focussed on preventive measures that is fully in line with the conclusions of the IDNDR and is a part of the International Strategy on Disaster Reduction. Procedures for strengthening the links among the national geophysical services, meteorological services, marine agencies, and counter-disaster and environmental organizations are proposed, as well as ways of establishing co-operation with regional and international organizations dealing with disaster reduction.

INTRODUCTION

Tsunamis are among the most destructive and complex natural disasters. They have been responsible for great loss of life and extensive destruction of property throughout the world. The significance of this hazard has greatly increased in the last 20 years due to the rapid growth and development of coastal areas in the developing and developed nations of the world. This is the result of a population explosion and of technological and economic developments in the coastal zones. Thus, mitigating of the effects of tsunamis is of considerable and increasing importance to the socio-economic development of Member States.

Tsunami events have been recorded in the Intra-Americas Sea (IAS) since the 16th Century (Lander *et al.*, 1999). Evidence for significant paleotsunamis is also found in the sediments of the Netherlands Antilles at 400-500 ybp, 1500 ybp and 3500 ybp (Scheffers and Kaletat 2001). Tsunami events are both local in origin and from distant sources but occur at the rate of one or more severe occurrences per century (e.g., Venezuela, 1530; Jamaica, 1692; Martinique, 1755; St. Thomas, 1867; Puerto Rico, 1918; Dominican Republic, 1946; etc.). The great Lisbon earthquake of 1755 created a tele-tsunami with 6 and 7 meter-high waves in the Lesser Antilles; its effect on the less populated areas such as the eastern Bahamas, Florida and Bermuda is unknown. So counter to the common perception (Gonzalez, 1999), the Atlantic Ocean, as well as the Pacific Ocean, is subject to these destructive sea waves (Annex I).

Although there have been deadly tsunamis in the Intra-Americas Sea this last century (1918: 42 persons; 1946: 1,790 persons by some recent reports; Lander *et al.*, 1999), it is the event of 1867 in the US Virgin Islands (Watlington and Lincoln, 1997) that is very reminiscent of the 1998 tsunami disaster in Papua New Guinea: juxtaposed earthquake epicentre; large nearly instantaneous tsunami; travel time in minutes; dense coastal population centres; uninformed populace.

If today re-occurred the 6-meter high tsunami wave observed in 1867 entering St. Thomas' Charlotte Amalie and simultaneously the 7 to 9 meter wave entering St. Croix's Christiansted Harbour, the 10-fold increase in population density, the cruise ships, petroleum carriers, harbour infrastructure, hotels and beach goers, would all be at immediate risk. Without preparation and warning it would be a disaster of catastrophic proportions.

In addition to the harbour investments since 1867 there now are nearby power plants, petrochemical complexes, marinas, condominiums, schools and other coastal structures. If several cruise ships are in Charlotte Amalie when the 1867 event re-occurs, direct economic damage of between US$500,000,000 and US$1,000,000,000 are quite possible; indirect damages (post event fires, disease, search and rescue, debris removal, electrical and telecommunication reconstruction, chemical and fuel tank failures, hazardous material cleanup, vegetation loss, salt water intrusion and environmental stress) could significantly raise these estimates.

The Caribbean Plate boundary is marked by active sub-aerial and submarine volcanoes, steep underwater slopes and numerous earthquakes. Certain submarine earthquakes, volcanic eruptions or sub-aerial and submarine landslides can generate tsunamis. In the central Lesser Antilles there have been several major volcanic sector collapses in the last 10-20 thousand years, and these are potentially very efficient tsunami-generating events.

To minimize 'false alarms' it must be quickly determined whether a seismic event creates a wave in the juxtaposed ocean. Seismic sea wave detection therefore requires both seismic and sea-level observations, integrated into a real-time operational telecommunications network. Some local IAS tsunamis if detected by such an operational network could easily provide 15 minutes of forewarning to many coastal site residents in the Caribbean Sea, Bahamas and the eastern USA, including the Gulf of Mexico and the Straits of Florida. Fifteen minutes warning is on a par with tornado warnings and is adequate, with the proper preparation, for most of the population at risk to evacuate to safe locations.

BACKGROUND

The Intergovernmental Oceanographic Commission (IOC) established in 1960 is performing a vital role in ocean science, services and international affairs by providing the essential framework for co-ordination and leadership of intergovernmental co-operation in understanding, observing, predicting and ultimately protecting the world's oceans.

The implementation of the IOC programmes through the collective efforts of its Member States has always been a central theme of the IOC. It has been based on the belief that the programmes can be best handled through a regional approach.

Within the IOC are 7 regional bodies, one of which is the Sub-Commission for the Caribbean and Adjacent Regions, or IOCARIBE. The IOCARIBE is responsible for programmatic development for the Caribbean Sea and Adjacent Regions and has its office in Cartagena, Colombia.

The IOCARIBE has several programmes that it attempts to develop through co-operation with Member States including: Ocean Science in Relation to Living Resources; Ocean Science in Relation to Non-Living Resources; Ocean Processes and Climate; Training, Education and Mutual Assistance; and Regional GLOSS, a component of the Global Sea Level Observing System (GLOSS), amongst others. The issue of an IAS tsunami is a concern of the IOCARIBE Group of Experts on Ocean Processes and Climate which is oriented towards physical oceanography and marine meteorology, and which has cross-cutting interests through several of these programmes.

The IOC has gained a worldwide reputation through implementation of the Tsunami Warning System in the Pacific (ITSU). This is a long-standing and successful programme, which helps to warn of and mitigate the impacts of devastating tsunamis. In operation since 1964, the IOC Tsunami

Programme has assisted in saving thousands of lives and billions of dollars in the Pacific and contributed effectively to the objectives of the International Decade for Natural Disaster Reduction (IDNDR).

Although the IOC Tsunami Programme has been centered in the Pacific for many years, there is no special regional significance to this beyond the proneness of the region to large earthquakes and hence to tsunamis. Recently, the Member States of the IAS, Indian Ocean and Mediterranean have been requesting more attention to tsunami warning in their respective areas.

In 1993, IOC with the assistance of the United Nations Environment Programme, proposed and conducted a Workshop on Small Islands Oceanography in relation to Sustainable Economic Development and Coastal Area Management in direct response to the needs of Small Island Developing States. The meeting was hosted by the Government of France in Martinique. One of the numerous issues discussed in Martinique was that of tsunami hazards. Many Small Island Developing States are located in the tropical waters of the Pacific and Indian Ocean, and are notably vulnerable to tsunami. It was noted too that the IAS and the Caribbean Sea in particular is a seismically active region and has a history of tsunami-caused by earthquakes and volcanoes.

At SC-IOCARIBE-V, the Fifth Session of the IOC Sub-Commission for the Caribbean and Adjacent Regions, the Recommendation of the IOCARIBE Group of Experts on Ocean Processes and Climate to hold a Caribbean Tsunami Workshop was adopted. The Eastern Caribbean Centre of the University of the Virgin Islands hosted the 2-day workshop in 1996 in St. John, at the request of IOCARIBE, which was attended by some 17 scientists. The attendees made it very clear (IOC, 1996) that the IAS has a record of significant tsunami-caused deaths and is at substantial risk for others (Smith and Shepherd, 1994).

The St. John scientific meeting led to the 1997 workshop at the University of Puerto Rico (Mercado, 1997). At Mayaguez, there were in attendance approximately 150 concerned citizens of the region, civil defence and government officials, scientists and tsunami warning experts, both local and from abroad. The Mayaguez meeting emphasized broader issues including education, warning, management, as well as research (Mercado and McCann, 1998; McCann, 1998; IOC Circular letter No. 1579, 1998, Gusiakov, 1999; Mofjeld *et al.*, 1999; Maul, 1999, Lander *et al.*, 1999).

All attendees at the June 1997 meeting in Puerto Rico were requested to contact their head-of-state with a statement of concern. In July 1997, USA President Clinton was formally informed of the recommendations made at the Mayaguez workshop. It focussed on 4 mitigation measures: education, warning, management and research.

In 1999, the proposal to establish an IAS Tsunami Warning System was encouraged by the officers of the International Co-ordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU) during their intersessional meeting in Hawaii (IOC, 1999). Later, in April 1999, in conjunction with SC-IOCARIBE-VI, the IOCARIBE Tsunami Steering Group of Experts gathered in San Jose, Costa Rica to draft this proposal. The Chairman of the Group wrote the final proposal details with input from interested parties including the IOC secretariat, the Pacific Tsunami Warning Centre and the International Tsunami Information Centre.

In 2000, the Thirty-third Session of the IOC Executive Council recommended to bring the experience and knowledge of the Pacific and Caribbean experts in Tsunami research and mitigation together in order to finalize the Tsunami Warning System (TWS) project proposal for the IAS region. The Mayaguez meeting was organized in December 2000 in compliance with the recommendation, and the draft project proposal was formulated.

In October 2001, the Eighteenth Session of ICG/ITSU was invited to comment on the text of the project proposal and propose modifications for submission of a final version to the IOCARIBE Sub-Commission's next session. After discussions, the ICG/ITSU accepted the proposal in principal

and formed a working group to address the remaining outstanding issues, take into account the comments that had been offered, and put the proposal into a final form (IOC, 2001). That work was completed and is the proposal presented here.

JUSTIFICATION

It is clear from the above that the tsunami threat in the IAS region is real and may cause tremendous damage to life, property, and infrastructure in all countries bordering the IAS. Everything possible must be done to minimize these disastrous effects.

The design of the IAS Tsunami Warning System will be implemented based largely on existing infrastructure and resources, e.g., sea-level measuring systems such as GLOSS, RONMAC and CPACC, co-operation with the WMO and OAS is envisaged; the seismic stations operated by Member States of the region and communication systems like those of WMO(GTS) and EMWIN will be involved. In setting up the TWS, the current institutional structures will be taken into account. The system will involve many organizations with varying expertise and emphasis in different system components. The Member States of IAS bordering both the Pacific and IAS regions have already gained invaluable experience in operating and contributing to the Tsunami Warning System in the Pacific. This experience should be exploited to the largest degree possible. The challenge is to develop an integrated network based on available experience, which will accommodate development of new requirements and capabilities.

Though there is some success in the region with respect to the collection of sea level and seismic data and in communicating them operationally to users, and some experience in tsunami warning systems operations, there are big gaps in data collection and communication systems and in tsunami mitigation in the region. There is a need for considerable improvement so as to bring about a better response and minimize loss of life and property. The gaps include:

- Need for reliable coastal and deep ocean monitoring stations;
- Need to verify and update existing sea-level and seismic stations to acceptable international standards;
- Need for additional TREMORS systems;
- Need for communication and data exchange systems that meet the requirements of the TWS;
- Need for numerical modelling to estimate the hazard, arrival time of tsunami and the inundation zones of the worst cases;
- Need for a special tsunami awareness programme and appropriate training;
- Need for a nationally and regionally co-ordinated approach to the establishment of the TWS;
- Need for links with existing relevant organizations, programmes and projects in the region.

This is not an all-embracing list; it is only a first approximation. It may be extended and adapted to new demands and challenges, when the project is being implemented.

As the TWS in IAS will be developed as a system to support sustainable social and economic development, welfare, and safety, the capacity building and awareness are essential as well as better scientific understanding of the tsunami phenomenon.

The project will develop and apply state-of-the-art tsunami models for inundation map development, tsunami risk assessment and evacuation plan formation. The project will place a strong emphasis on education for appropriate public response. The timely response to tsunami warnings of the public and of the disaster prevention and preparedness organizations is extremely important to minimize the loss of life and property.

SYSTEM COMPONENTS

To mitigate the tsunami hazard, it is critical to accurately assess the nature of the threat posed by the hazard, to design and implement a warning technique and to prepare at-risk areas for appropriate actions to reduce the impact of the hazard. That is why the Tsunami Warning System structure in the IAS region will be based on the following 3 pillars: hazard assessment, warning and preparedness.

Hazard Assessment

To find out what type of warning system is required, a background approach is used. As the first step, an assessment of the tsunami hazard for each coastal community will be made to identify populations and assets at risk and the level of that risk. To assist in this effort a historical tsunami database for the Caribbean (Lander et al., 1999) will be improved and made available in a form more easily and rapidly accessible to users. A graphical interface for these data has already been developed by the Tsunami Laboratory of the Siberian Division of the Russian Academy of Sciences (example output is shown on their web site at http://omzg.sscc.ru/tsulab/carib.html). For communities with very limited or no past data, numerical models of tsunami inundation can provide estimates of areas that will be flooded in the event of a local or distant tsunamigenic earthquake. This information can later be used for creating tsunami evacuations maps and procedures.

The experience of the IOC ICG/ITSU in its implementation of the Historical Tsunami Database (HTDB) and Tsunami Inundation and Modeling Exchange (TIME) projects for the Pacific region will be very useful.

Warning

To alert coastal communities that danger from a tsunami is imminent, an appropriate warning system is required. Tsunami warning systems rely on seismic data and earthquake analysis for the rapid initial warning, and on sea level data for confirming and evaluating the tsunami and for continuing, upgrading, or cancelling the warning. Warning systems also rely upon a variety of communication methods to receive seismic and sea level data and to issue messages to appropriate authorities.

Seismic Subsystem

The IAS has several seismic reporting systems in place. The Seismic Research Unit at the University of the West Indies has been in operation since 1952 and the Puerto Rico Seismic Network has operated the data centre for the Middle-America Seismograph Consortium (MIDAS) since 1998. A protocol has been established for participating seismic networks of the Caribbean, North America, Central America and South America to submit data on significant events in the region in near real time. This issue has already been widely discussed at the two Caribbean Tsunami workshops already held, St. John, USVI (IOC, 1996) and the Mayaguez UPR Workshop in 1997 (Mercado, 1997; Maul, 1999), and at the Peru 1997 meeting of the ICG/ITSU-XVI and the Hawaii 1999 meeting of the Officers of the ICG/ITSU (IOC, 1999). At several MIDAS meetings, the desirability of having seismic data exchanged in real-time has been discussed for tsunami warning applications.

Other seismic systems operated by the French in Martinique and Guadeloupe and by the Seismic Research Unit of the University of the West Indies from Saba to Trinidad have experience in detecting potential tsunamigenic events. The Eastern Caribbean has a very high density of seismographic stations -- each major island has at least one 3-component digital broadband seismograph.

The Caribbean Development Bank has funded the Seismic Research Unit to instrument Kick 'em Jenny volcano and several sites in nearby islands for detection of volcano-generated tsunamis. The Intra-Americas Seas Tsunami Warning System will capitalize on this parallel effort through co-operation and communication.

TREMORS (Tsunami Risk Evaluation through seismic MOment from a Real-time System) is considered the most effective stand-alone warning system for tsunamis generated by earthquakes. It is based on a single 3-component broadband seismometer connected to a personal computer where special software is continuously running. It automatically detects the arrival of seismic waves from any large earthquake, locates the epicentre, and computes the seismic moment. Depending on the results, the system is capable of sending a short message, including all the results, through INMARSAT. It can also send a warning to a telephone and set off an alarm tone on the personal computer. TREMORS is capable of detecting and analyzing potentially tsunamigenic earthquakes at regional distances within the IAS and far distances such as across the Atlantic.

In order to organize effective warnings there should be a minimum of at least 6 TREMORS stations as the Caribbean region is vast and the future warning system should monitor 2 distant regions (the first: the eastern and northern part of the Caribbean from Cuba to Trinidad, and the second: the western part where the Cocos plate subducts under the Caribbean plate). Three stations will be installed in each of the regions running at the same time. However, taking into account possible downtime at any of the stations, it is recommended to have 8 stations for an optimum configuration. It is proposed to have sites in the following states: Colombia, Costa Rica, Cuba, Guadeloupe, Mexico, Puerto Rico, St. Vincent and Venezuela. Ideally, it is desirable to have additional TREMORS (in addition to the proposed 8) in the Central American Zone, in the northern part of the Caribbean and the West Indies islands. In the proposed locations there already exist or are plans to install broadband seismic stations. The characteristics of the existing stations are in Annex II. The institutions responsible for these stations must be consulted to see whether TREMORS can be added on. The only additional cost for existing broadband stations will be the INMARSAT transceiver and the TREMORS software.

With the proposed set of broadband stations and TREMORS systems, large magnitude events can be quickly recorded without the signal going off scale and the seismic parameters can subsequently be determined. The goal is for this network to be capable of notification of a major earthquake in the IAS within 2 minutes of the initial rupture. This notification will be followed within 3 minutes by detailed seismic parameters that provide an understanding of the likelihood of a tsunami. The TREMORS network will also be capable of notification of a major trans-Atlantic earthquake within about 10 minutes of its occurrence with detailed seismic parameters within about 45 minutes.

The seismic warning system must be complimented by first order estimates of travel times and wave heights for all the most likely sources based on numerical simulations.

Sea-Level Subsystem

Water level gauges are an essential element of TWS. When strategically located they are used to quickly confirm the existence or non-existence of tsunami waves following an earthquake, to monitor the tsunami's progress, to help estimate the severity of the hazard and to provide a basis for declaring the hazard over. Water level gauges may also be the only way to detect tsunamis in cases where there is no seismic data or when the tsunami is not earthquake-generated.

The TWS in the IAS region needs a reliable network of operational coastal and deep ocean monitoring stations. The inventory of existing coastal stations is in Annex III.

This list shows there are probably a sufficient number of coastal stations, although verification of some of them needs be made. Several existing stations need upgrading to international standards for tsunamis as defined by ICG/ITSU. Many of the sea-level gauges are mechanical instruments without telemetry capability. The programmes of OAS, such as CPACC (Caribbean: Planning for Adaptation to Climate Change) and RONMAC (Water Level Observation Network for Central America) offer the best opportunity for establishing a regional sea-level network because each

instrument transmits its data via GOES and are GPS-located. The position of the CPACC and RONMAC stations and their technical specifications are in Annex IV.

There may be a need for some new stations on certain islands (for example, Isla de Aves, San Andres, Swan Island, St. Martin, La Blanquilla). Some existing sea-level stations require installation of additional hardware in the Data Collection Platform (DCP) and the acoustic controller to be used for tsunami monitoring. Key criteria for selection of sea-level stations should be spatial location.

Warning Centre(s)

Two approaches can be considered: 1) a TWS with one or more central warning centres to receive and intrerpret the TREMORS and sea level data and generate regional or widespread warnings, and 2) a TWS where data are sent directly to each Member State of the IAS for their own local interpretation and warning. Either approach or a combination of both can be implemented. There are trade-offs in cost and capabilities regarding these options. A central centre must have at least 5 full-time professional personnel to enable one-person 24-hour operations, but it can provide expertise in the interpretation of the seismic and sea level data to help reduce false warnings and it

Figure 1. The proposed flow of seismic data and tsunami bulletins. Multiple TREMORS systems report the detection of large earthquakes and then the earthquake parameters to the warning centre(s) via INMARSAT. The centre(s) subsequently transmits appropriate tsunami bulletins to the San Juan Puerto Rico Weather Forecast Office for relay into the Emergency Managers Weather Information Network (EMWIN). Member States receive the bulletins via EMWIN from the GOES satellite using an inexpensive receiver and software that can be programmed to trigger an audible alarm, commercial page, or telephone call if a tsunami warning is received.

may ultimately be able to provide wave height forecasts based on numerical simulations. The warning, however, may be somewhat slower due to this layer of interpretation. By receiving the field data directly, each Member State has the possibility to respond immediately to TREMORS transmissions and later sea level data. However, this also requires a 24-hour response capability and expertise in interpreting the data. The decision regarding the most suitable way to configure the system is left to the Member States of the IAS. However, for this proposal only a system with a central warning centre(s) will be further discussed.

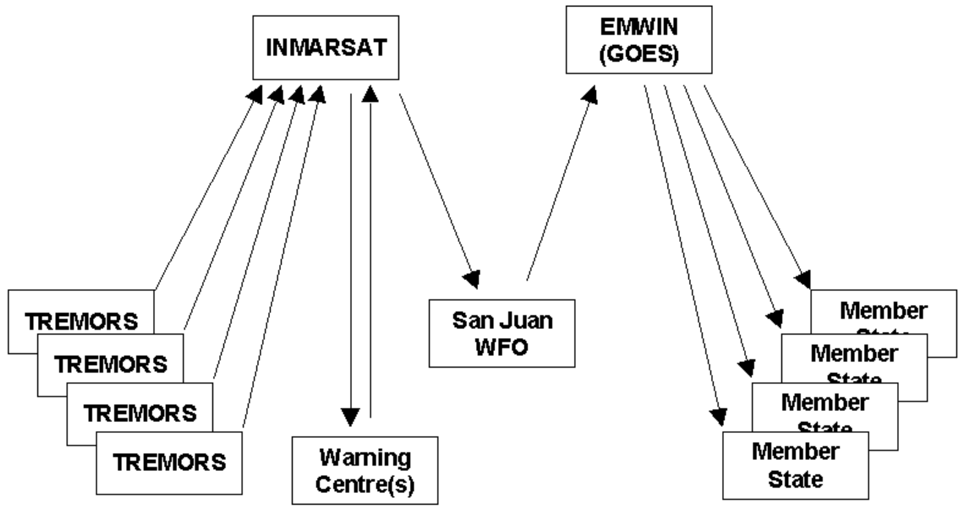
Communication and Data Exchange Subsystem

Tsunami Warning Systems have unique and extensive communication requirements. Seismic and water level signals must be sent from remote sites, often without power or telephone lines, and warning messages must be transmitted quickly and reliably to users having different means of access.

In the IAS region the distances to be covered range from less than a kilometre to hundreds of kilometres.

The communication system should be as independent of the normal communication circuits as possible. This will enable users to get data in and information out regardless of what happens to the local communication infrastructure.

Data from individual TREMORS systems will be transmitted via INMARSAT C to the warning centre(s) and/or Member States using equipment purchased as a part of the seismic component. After the data are evaluated by a warning centre, the appropriate tsunami bulletin (informational, advisory, watch, or warning) is transmitted to the San Juan Weather Forecast Office (WFO) via INMARSAT C. It is then forwarded into the Emergency Managers Weather Information Network (EMWIN) for transmission to individual Member States. This will require an INMARSAT ground station at the San Juan WFO and EMWIN receivers and software at each of the 33 Member States of the IAS. Sea level data that are transmitted via the GOES satellite will be relayed from the downlink at Wallops Command and Data Acquisition facility to the NWS central communications



gateway where it will be sent to the San Juan WFO or entered into EMWIN for distribution. Methods to acquire sea level data from across the Atlantic, possibly via METEOSAT, for the evaluation of teletsunamis will be explored.

The public Internet, which has greatly improved and expanded in the IAS region, should be considered as an alternate or supplemental method for communication needs in the TWS.

Dissemination of tsunami watch or tsunami warning messages to the public will be accomplished using the existing meteorological communication network and systems like GTS or the Aeronautical Fixed Telecommunications Network (AFTN). Messages can also be transmitted widely through commercial circuits, such as telex and the Internet. On local or national levels, tsunami messages can also be sent over text or voice circuits designed for national defense or other emergencies. Messages can also be sent by telephone or fax. Within each country consideration will be given to strengthening existing communication networks and implementing new ones.

Preparedness

Activities in this category take place in order to achieve an appropriate level of preparedness for a warning of impending danger from the tsunami. They will include creating and disseminating knowledge about potential tsunami inundation, about the warning system, about evacuation preparation and procedures, and regarding land use planning. A community-wide effort of tsunami hazard awareness is essential to educate the residents as to the appropriate action to take in the event of a tsunami. A public information campaign will be mounted to make sure that the information gets through to the general public.

The response of the public and disaster prevention and preparedness organizations to tsunami warnings is most important to minimize loss of life and property. The current reaction by the emergency management community in the area is slow. The lack of a current quick response capability to a warning is another argument in favour of the establishment of a warning system.

One of the major efforts in operation of the warning system will be one of education not only of the public but of those agencies and people who have to respond/react to natural disasters. A concerted effort using sea-level and seismic stations and communication facilities will require additional training through the organization of workshops and training courses.

Regional workshops will be held to develop an appropriate set of pilot projects, e.g., modelling and analysis; data and information management; methods of risk assessment and tsunami

warning system operations. It is recommended to use the expertise of the TEMA programme of IOC and the equivalent programmes of WMO, UNEP and other international organizations in implementing these activities.

Awareness education will include the implementation of an education programme for schools to prepare students at all age levels, the co-ordination of periodic public drills to maintain the preparedness level, the development of a search and rescue plan, and the involvement of community organizations to educate all sectors of the population at risk. Communities must be committed to a continuous long-term institutionalized education programme as tsunamis are infrequent events and succeeding generations may forget tsunami safety lessons.

The need for 3 areas of training is identified: seismic station operation (equipment and station maintenance, seismology, TREMORS software, etc.); tsunamis generated by submarine landslides and volcano eruptions (nature, evaluation of tsunami risk, organization of underwater and post-disaster surveys, etc.); and numerical modeling (travel time charts, historical tsunamis, TIME, etc.).

The IOC has long experience in assisting countries in implementing tsunami awareness and education programmes. Written educational material in English, Spanish, French and Russian, educational curriculums, videos and reports from communities with comprehensive awareness programmes are available through ITIC and the IOC Secretariat. New flyers and brochures must be developed using the ICG/ITSU experience to reflect better regional peculiarities and culture. English, French, and Spanish versions will be widely distributed through the IOC Regional Office and other appropriate channels to schools, civic organizations and religious institutions. More generic natural hazard brochures should be identified and updated to include tsunami information. Finally, a professionally produced multi-lingual video should be taped and made available for broadcast and duplication (this should be encouraged by a special copyright freedom).

It is anticipated that a general reluctance by certain business, insurance, and political groups will be encountered. Recruiting these persons and organizations in the context of thoughtful, non-hysterical, planned contact will be challenging and rewarding. It is essential not to overstate the hazard, yet to be firm and apolitical in such dealings. In this regard, the cultural context of the community must be appreciated and respected. Regular and persistent communication by mail and in person will be required to convince reluctant sectors of the community to refocus their perspectives.

NON-EARTHQUAKE GENERATED TSUNAMIS

Tsunamis generated by submarine landslides and volcanic eruptions cannot be detected automatically at the present time. The time an eruption or landslide will occur in a specific zone generally cannot be predicted with enough accuracy and further research must be carried out. Nevertheless, it is possible to survey coastal and submarine slopes and evaluate the potential tsunami hazard from volcanoes or landslides for harbours and coastal villages situated close to the zone of generation.

Volcanoes do not generate tsunamis without a preliminary period of activity. The volcanoes themselves should be monitored in order to recognize when they might be about to generate a tsunami. The Kick ‘em Jenny monitoring project funded by the Caribbean Development Bank is an example of how such monitoring should be organized and implemented.

For on-land volcanoes there will be a need to know more about past tsunamigenic events such as major collapses from the volcanoes of the central Lesser Antilles. Natural collaborators in implementing this study will be from Caribbean proper, primarily from Venezuela whose coasts and islands are exposed to tsunamis from the Lesser Antilles.

SUMMARY OF BENEFITS AND BENEFICIARIES

Member States of the IAS region are the first countries to benefit from the project by the development of institutional, national and regional infrastructures for the tsunami warning system. In addition, European and African countries will benefit from the IAS TWS in case transatlantic tsunamis occur.

The target beneficiaries of the project will be all coastal communities of the countries concerned. The users of the tsunami information are likely to be governmental agencies, including safety, search and rescue and environmental departments, planners for coastal land use, individual enterprises, insurance companies, scientists and the public.

The benefits of the project can be summarized as: reduction in the loss of life and property; reduction in damage to infrastructure and land; increased stability of local economy and more dependable investment; improved cost-effective coastal engineering including design of local coastal defenses; increased knowledge in seismology and tsunamis; increased scientific and technical capacity and finally, strengthening of existing national and regional institutions, facilities and programmes, as well as of co-operation between Member States and governmental and non-governmental organizations with tsunami-related interests in the region.

To give a quantitative estimate of the potential benefits of the projected TWS in terms of dollars is difficult, as potential products and beneficiaries are diverse and the cost details are not easily available. In documented cases, cost/benefit ratios of weather warning services have been put in the range of 1:55 to 1:217. For the development of a regional SeaWATCH system, it is in the range of 1:20 to 1:50. We may expect that benefits provided by the products and services of TWS to different users will also be in this range. While the system, when established, will not avoid all damage and will depend on the capacity of decision makers to respond effectively in advance to the threat and then to the warning, it will have the potential to save many millions of dollars at a cost of a few million dollars.

MANAGEMENT AND ADMINISTRATION

If the proposal is adopted by the IOCARIBE Regional Sub-Commission it will then be sent to the IOC Executive Council session of 2002 for approval. At the same time, it should also be distributed to interested regional and international in organizations for information and support. It will be accompanied by an Action Plan based on the proposal developed by the IOCARIBE Tsunami Steering Group of Experts with the assistance of a consultant(s). The proposal, if approved, will be presented to potential donors for funding. The OAS will co-operate with IOC in looking for funds, especially within the region. There will be a need to bring together all the stakeholders so as to achieve an integrated approach in designing and implementing the TWS.

Individual nations should put their faith and resources in a collective tsunami warning system. At the national level, responsibilities must be assigned to individuals to ensure that someone is looking after a particular element of the system. Each country will create a national co-ordination committee to regularly evaluate the progress of the project and recommend appropriate actions for the better development of its national system to the governmental authorities concerned. The ICG/ITSU will help the countries of the region by developing guidelines for national participation in the TWS.

The implementation of the project will be the responsibility of the national authorities as far as possible within the existing institutions along the national action plans, with clear objectives and milestones for the development of each element of the system.

There is a recognition that Small Island nations in the region may find it difficult to participate in, contribute to the TWS and make long-term commitments to the system's operations. External resources from regional/international funding agencies will be essential and sought.

The management of the project will be carried out in accordance with the agreements among participating governments and funding institutions. The implementation will be undertaken under the general direction of the participating member countries with the technical assistance of international agencies and appointed experts/consultants.

The project will have a Chief Technical Adviser(s) from inside or outside the region whose main function will be to advise national authorities concerned on technical and scientific matters related to the project, as well as on plans for the mitigation of tsunami hazards; and to provide overall supervision of the project to ensure satisfactory implementation of its various components.

If the region decides to take a centralized warning approach, then a Regional Tsunami Warning Centre for the IAS might be established, for example, at the Mayaguez Campus of the University of Puerto Rico, which has the necessary experience in tsunami research and mitigation and the required facilities. It is recommended to also create a Regional Tsunami Information Centre in the same place under the direct supervision of the Chief Technical Adviser. There will also be arrangements for regular monitoring and reviews of progress in achieving specific objectives of the project.

It is recommended that an IAS TWS Project Steering Group (PSG) be formed with the Chairman of the existing IOCARIBE Tsunami Steering Group of Experts, the Chief Technical Adviser and representatives of project funding agencies and system members. Among the responsibilities of the PSG, will be to review the Plan of Operations and Implementation schedule prepared by the Executing Agency and advise on matters related to the implementation phase.

The IOCARIBE Tsunami Steering Group of Experts, consisting of scientific leaders appointed by countries with the assistance of the ICG/ITSU and IUGG Tsunami Commission, will provide scientific backing to the project and will help build bridges between the scientific community and policy makers.

Taking into account the existing successful practice of implementation of many international projects and programmes, Working Groups may be established to deal with specific problems of the region related to the TWS project and their causes.

Once funding is obtained, the OAS or another regional organization will be contracted as the Executing Agency (EA) with the responsibility for the detailed design and implementation of the programme. The Project Co-ordinator will be nominated in consultation with the IOC, and with national and international agencies sponsoring the project.

The EA will be responsible for the technical supervision and administrative co-ordination of its implementation. It will also design and implement a public awareness campaign on the tsunami hazard and the need for tsunami preparedness. This campaign will make extensive use of already available material and will engage the national and regional disaster management offices in its implementation.

It will establish, as required, co-operative agreements or memoranda of understanding with the regional institutions and national governments or their specialized agencies. It will be accountable to the agency(ies) providing the funding for the implementation of the system and will be responsible for the timely production of the necessary technical and financial reports.

The following are among the principal responsibilities of the EA:

- Develop a detailed Plan of Operations for the installation of a fully operational IAS Tsunami Warning System (IAS-TWS);
- Contract a full-time Project Co-ordinator and provide the Co-ordinator with the necessary technical and administrative support for the duration of the project;

- Establish and maintain regular and effective communications with the IAS-TWS Steering Group, participating countries, and regional/sub-regional institutions;
- Develop and implement a public education and awareness campaign aimed at increasing the awareness of the tsunami hazard and generating the necessary support and participation in the IAS-TWS among vulnerable communities and key institutions;
- Develop and implement the necessary institutional arrangements and co-operation agreements with participating institutions and governments;
- Contract the necessary short-term technical expertise for the detailed design of the IAS-TWS system components and for their installation in the field;
- Procure all equipment and technical services necessary for the establishment and full operation of the IAS-TWS;
- Develop technical and administrative management procedures for the functioning of the IAS-TWS following its establishment;
- Produce timely progress and financial reports to the PSG and for the agency(ies) funding the implementation phase;
- Participate in negotiations with donors for funding of the continued operation of the IAS-TWS;
- Ensure the necessary co-ordination with other related programmes and projects;
- Launch the system.

The outcome to be delivered by the EA will be a fully operational IAS Tsunami Warning System co-ordinated by a Technical Office located in one of the participating countries/territories and with full participation of specialized regional/sub-regional institutions and national agencies (the system members).

IMPLEMENTATION

Full implementation will require 3 years. The 3-year (funded) implementation phase is as follows: Year 1 is dedicated to naming an interim Director, establishing an office and expanding the educational effort beyond that. Included in this first year will be an educational video and establishing regular annual meetings of government and non-government activists. The office location will be a political decision but one based on the 4 technical requirements (elements) of the Tsunami Caribbean Workshop: 1. Education. 2. Warning. 3. Management, and 4. Research. By the end of Year 2, an operational staff and office will be established. Much of the second year's efforts will have been to install the additional field instrumentation and communications links necessary for broadcast warnings. The research component will have been defined at this time and the management effort in place. Year 3 is the first full operational period and will have activities in all 4 elements. As with the other start-up years, the governmental parties will review the effort and instruct the TWS Project Co-ordinator as appropriate.

The Project Co-ordinator of the IAS-TWS will make quarterly reports to the PSG. The annual meeting of the Member States will be the normal means of communication to government and non-governmental organizations. These meetings shall be highlighted with press releases and other activities to promote public awareness.

BUDGET

A three-year implementation and budget is proposed based on the recurring theme from the 1997 Caribbean Tsunami Workshop: education, warning, management, and research.

The project will organize a training program on the concepts and techniques of hazard assessment and mapping, vulnerability analysis, and the assessment and mitigation for key planning and sectoral agencies, including the national disaster offices. The core elements of this program will be offered at the regional level, accompanied by specific follow-up activities at the national level,

including the formulation of mitigation strategies and measures, and the linkage of these measures to existing national and sectoral development plans. Training, Education, and Mutual Assistance (TEMA) Programmes will focus on the CPACC methodology of in-country training of the observers and technicians. An annual TEMA within-region technical meeting for involved personnel and supervisors is required. Education, capacity-building, awareness, and TEMA are estimated at $192,000, $75,000 of which is directed to broad public outreach, signage, in-service teacher training, and teaching materials.

There is a requirement for reliably operating coastal real-time reporting tide gages, as well as monitoring stations using isolated small islands. From the inventory of existing coastal stations (Annex III), there seem to be sufficient coastal stations, but many are not real-time reporting systems. Several of the existing stations need upgrading to the ITSU standard for tsunamis. New island stations needed as a minimum include Isla de Aves, San Andres, Swan Island, St. Martin, and La Blanquilla. Summary of costs using a judicious mix of ITSU and CPACC standards is $340,000 (Annex IV). Upgrading existing CPACC-type stations with tsunami monitoring capability requires installation of additional hardware in the DCP equipment and the acoustic controller. The DCP for tsunami monitoring purposes requires that all sea level stations use GOES satellite links to transmit information. A backup GOES ground station is recommended, at an additional cost of $35,000. Not all existing tide stations are needed for tsunami warning, but they will greatly enhance the research component (where spatial location is a key selection criterion), and add to the other benefits stemming from modernization.

To provide emergency managers with timely earthquake magnitude, location, and tsunami probability information, TREMORS systems are recommended for the seismic analysis. This seismic component recommendation includes upgrading three existing ultra-broadband seismic stations, and the installation and start-up of five new TREMORS stations, for a total cost of $265,000. Included in this budget are the software installation, and the training necessary for competent operation. New TREMORS stations will be located at existing seismic centres (Annex II) and will include training on-site plus one in-region workshop for all participants. This seismic educational component is in addition to the activities described in the second paragraph of this section of the proposal. As with the sea-level component and the communications network, the seismic budget includes broader goals for capacity building and technology transfer.

Warning centre operations require a minimum of 5 full-time employees to have one person on duty continuously. The Puerto Rico Seismic Network, for example, would require two-person shifts for this work, with one professional analyst and one electronic technician on duty each shift. They estimate the additional cost to their current operations at $275,000 per year, with up to 10% per year additional for salary adjustments. Centre operations are not anticipated until the second and third year of the project. Thus, the total cost for warning centre operations in this proposal is estimated at $625,000.

The Unit for Sustainable Development and Environment of the Organization of American States (OAS/USDE) has expressed interest in acting as Executing Agency (EA) for the IAS Tsunami Warning System. In that capacity, the OAS/USDE would be responsible for the detailed design and implementation of the Program, expanding on their experience and success with CPACC. The outcome to be delivered by the EA is a fully operational IAS Tsunami Warning System, including components in education, warning, management, and research. The implementation will be coordinated by a technical office located in one of the participating countries, and with full participation of specialized regional/sub-regional institutions and national agencies (the program members). A three-year effort is required including procuring funding, equipment purchase and installation, training, operations start-up, and turnover of a fully operational system. The OAS/USDE estimate for the three-year EA activity is $469,000.

Research needs include improved bottom topography data; tsunami wave arrival amplitude estimation; potential for tsunamigenic volcanic eruptions; potential for landslides and submarine

slumping; detailed fault structure; inundation mapping; paleo-tsunami dating and description; and improvements to the tsunami and earthquake historical databases, amongst others. Research is fundamental to the graduate education of the next generation of oceanographers, coastal engineers, seismologists, volcanologists, coastal zone managers, geochemists, psychologists, emergency managers, environmental economists, sociologists, infrastructure planners, and so forth in the region. Accordingly, a substantial research element is included, and is budgeted at $250,000.

Budget Summary:

Education, Capacity Building, and Awareness	US$192,000
Sea-level Infrastructure Modernization	US$375,000
Seismic Infrastructure Modernization	US$265,000
Warning Centre Operations	US$625,000
Communications Infrastructure Modernization	US$250,000
Executing Agency	US$469,000
Tsunami Research	US$250,000
TOTAL	US$2,426,000

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Annex I. Preliminary List of Historical Caribbean Tsunamis

Date	Area	Location of Effects	Runup(m)	Comments
1530 09 01	Venezuela	Paria Cumana Cubaqua	7.3	Ground opened emitting black salt water and asphalt. Mountain at the side of the Gulf of Cariaco was cleft (earthquake). A fort and many houses destroyed, but not clear whether due to the wave, the earthquake, or both.
1543	Venezuela	Venezuela		Waves noted. City of Cumana destroyed by earthquake?
1688 03 01	Jamaica	Port Royal, Jamaica		Shocks felt throughout the island and waves damaged ships in Port Royal. A ship at sea was damaged by a hurricane.
1690 04 16	Leeward Is.	Charlotte Amalie, Virgin Is. Charleston, Nevis		The sea withdrew from Charlotte Amalie, St. Thomas, (16.5 to 18.5 m). Earthquake of intensity IX caused landslides on volcanic Nevis Peak which caused the sea to withdraw 201m from Charleston before returning in 2 minutes.
1692 06 07	Jamaica	Port Royal, Jamaica		Earthquake and subsidence destroyed the city. Ships overturned, frigate washed over tops of buildings. Along the coast of Ligance (possibly Liguanea Plain) the sea withdrew 18.3 or 274m, exposing the bottom; upon returning the water overflowed the greater part of the shore. At Yallhouse (possibly Yallahs) the sea is said to have retired about 1.6km. At Saint Anns Bay a large wave was report. 2000 people killed by the earthquake and tsunami.
1755 11 01	Lisbon, Portugal	Saba St. Martin Antigua & Dominica Barbados Martinique Santiago de Cuba	7.0 4.5 3.6 1.5-1.8	At St. Martin, a sloop anchored in 4.6 m of water was left lying broadside on the dry bottom. At Barbados, the wave had a period of 5 minutes and the water was black as ink. This could be a local landslide tsunami or seiche triggered by the Lisbon wave. At Martinique, at some places the water was reported to have withdrawn for 1.6km and at other places it flowed into the upper level rooms of the houses. The lowlands on most of the other French Islands were inundated. There is a report of Santiago de Cuba being nearly inundated in 1755, but the month and day were not given. This is probably from the Lisbon tsunami.
1761 03 31	Lisbon, Portugal	Barbados		An earthquake near Lisbon, Portugal caused an extraordinary flux and reflux of the sea at Barbados.
1766 06 11	Cuba	Jamaica		An earthquake lasting 1-1/2 to 7 minutes hit Cuba. Ships at sea 7.2km from the coast of Jamaica rolled so much that their gunwales were immersed in the water. Ships in deep water would not experience a tsunami. Either the ships were near the coast or in shoaling water or the wave was a storm wave but no storm was reported.
1766 08 21	Venezuela	Cumana, Venezuela		Very violent shocks raised Cumana and caused the island of Orinoco to sink and disappear. In many placed the water surface was disturbed. This is a possible tsunami report.
1767 04 24	Martinique & Barbados	Martinique Barbados		The sea was much agitated and ebbed and flowed in an unusual way.
1770 06 03	Haiti	Golfe de la Gonave, Haiti		La Saline Mountain foot partly submerged. The sea inundated 7.2km inland.
1775	Hispaniola & Cuba	Hispaniola Cuba		Three earthquakes reported and waves did extensive damage.
1780 10 02	Jamaica	Savanna la Mar, Jamaica	3.0	An earthquake occurred during a hurricane. The sea rose to a height of 3m at 0.8km from the beach and swept away a number of houses. Ten people were killed by the wave and at least 40 more by the storm. All vessels in the bay were dashed to pieces or drive onshore.
1781 09 01	Jamaica	Jamaica		In 1781 a series of waves and disastrous earthquakes nearly ruined the Island.
1787 10 27	Jamaica	Montego Bay, Jamaica		A small local shock was felt at Montego Bay and the vessels in the harbor were agitated. Mallet reports earthquakes in Jamaica on Oct. 1 and 21 at Kingston and Port Royal. This would be a low validity report as no wave was cited and the agitation may have been a report of a seaquake effect.
1802 03 19	Leeward Is.	Antigua St. Christopher		Earthquakes were reported in February and March with the largest on this date. It was accompanied by great agitation of the sea. Intensity IV.

Annex I. Preliminary List of Historical Caribbean Tsunamis (continued)

Date	Area	Location of Effects	Runup(m)	Comments

1802 05 05	Venezuela	Orinoco River, Venezuela		Earthquakes at Cumana caused the water of the Orinoco River to rise so high as to leave part of the bed dry. This could describe wave action near the mouth of the river, or bore action.
1812 11 11 or 12	Jamaica	Jamaica		The sea was much agitated following an earthquake. This could describe wave action or seaquake action.
1823 11 30	Martinique	Saint-Pierre Harbor, Martinique		At 3:10pm, a strong undulation (earthquake) was followed by a tidal wave which caused some damage in Saint-Pierre Harbor.
1824 09 13	Guadeloupe	Plymouth, Montserrat		Earthquakes were felt at Basse Terre on the 9th and on the 13th; there was remarkable rise and fall of the tide at Plymouth, Montserrat. There had been a terrible storm and heavy rain on September 7-9.
1825 09 20	British Guiana	Demerara County, British Guiana		Local earthquake and oscillations of the sea were noted. An earthquake was also noted at Trinidad, Tobago, St. Vincent, and Barbados.
1831 12 03	Trinidad and St. Christopher	Trinidad St. Christopher		An earthquake occurred. The sea was in a state of violent agitation. Note the large distance between reporting areas. An earthquake was also reported in Grenada, St. Vincent, British Guiana.
1837 07 26	Martinique	Martinique		Several shocks accompanied by a large wave occurring during a hurricane. Source of wave uncertain.
1842 05 07	Guadeloupe	Guadeloupe: Basse Terre Deshaies, & Sainte Rose Bequia Is. St. Johns, Virgin Is. Charlotte Town, Grenada Haiti: Cap Haitien, Port-de-Paix, Fort Liberte, Mole St. Nicolas, & Santiago de los Caballeros	0.9 8.3 1.8 3.1	A strong earthquake produced waves with heights reported; a wave carried away all floatable objects at Deshaies and Sainte Rose; at Gouyave, Grenada (Charlotte Town), there was some damage; at Haiti, a destructive tsunami struck the north coast; at Mole Saint-Nicholas, Ca-pHaitien, there was extensive destruction caused by the earthquake and tsunami; at Port-de-Paix the sea receded 60 and the returning wave covered the city with 5m of water. About 200 of the city's 3,000 inhabitants were killed by the earthquake and tsunami. It was observed at Fort Liberte, Mole Saint-Nicholas, and Santiago de los Caballeros. At Hispaniola, there was destruction on north coast. Note the large area of this event which suggests a teletsunami, but the earthquake was felt at Haiti, Jamaica, Puerto Rico, and other islands. Note also the missing locations such as Puerto Rico for which no tsunami report is available although there are reports from Haiti and the Virgin Islands.
1843 02 08	Antigua			An earthquake was felt at Point-a-Pitre, Guadeloupe, St. Lucia, St. Kitts, Montserrat, Martinique, and other islands. The sea rose 1.2m but sank again immediately.
1853 07 15	Venezuela	Cumana, Venezuela		A violent earthquake in Cumana followed by a tsunami.
1860 03 08	Hispaniola	Hispaniola: Golfe de la Gonaves, Cayes, Acquin, & Anse-a-Veau		An earthquake was reported from Port-au-Prince and Anse-a-Veau. Waves were reported from Golfe de la Gonaves, Cayes, and Acquin. At Anse-a-Veau, the sea withdrew and broke with a crash on the shore.

Annex I. Preliminary List of Historical Caribbean Tsunamis (continued)

Date	Area	Location of Effects	Runup(m)	Comments
1867 11 18	St. Thomas, Virgin Is.	St. Thomas, Charlotte Amalie & Altona St. Croix, Fredricksted, Christensted & Gallows Bay Puerto Rico, San Juan, Fajardo, Yabucoa & Vieques British Virgin Is.: Tortola, Road Town, Peter is., Saba, St. Christopher, St. Martin & St. Barthelemy St. Johns, Antigua Guadeloupe: Basse-Terre, Deshaies, Isles des Saintes, Fond du Cure, Pointe-a-Pitre & Sainte-Rose Martinique St. Vincent Grenada, Charlotte Town	6.0 7.6 1.5 1.5 3.0 1.0 10.0 3.0	At Charlotte Amalie the height was 2.4m above the sea level at the wharf, and the lower part of the city was flooded. The water receded nearly 100 and returned as a wave 4.5 to 6m high, swamping small boats in the harbor. The wave penetrated 76m inland. The USS De Soto was damaged, 11-12 people were killed. At Altona, houses were washed far inland and there was some damage at Hassel Is. At Christensted, St. Croix, waves swept inland 91m, and at Gallows Bay, 20 houses were damaged. At Fredericksted, the sea withdrew and returned as a wall of water 7.6m high leaving the USS Monongahela stranded. Five were killed, 3-4 injured, and 20 houses were damaged. At Puerto Rico, at San Juan, the river water rose 0.9-1.5m and at Vieques, high waves were observed. At Fajardo, a very small wave was reported, and at Yabucoa the sea retreated and inundated 137m on its return. In the British Virgin Islands, at Peter Is., a wave was noted and people fled to Tortola. At Roadtown, Tortola, a 1.5m wave swept some houses away. At Saba, there was some damage. At St. Christopher, the wave was also observed. At St. Martin and St. Barthelemy, there was some damage. At St. Johns, Antigua, the wave had a height of 3.0. At Basse-Terre, Guadeloupe, the height was 1.0m with the sea retreated far from coast. At Deshaies, houses in village were destroyed. At Isles des Saintes, there was a slight swell, and at Fond du Cure, houses inundated to a depth of 1m. At Point-a-Pitre, there was a slight swell, and at Sainte-Rose, a 10m wave. The sea withdrew 100m and flooded and damaged houses on return. It was observed at Martinique and St. Vincent had unusually high water. At Grenada, Gouyave (Charlotte Town) the height was 3m and at St. George, 1.5m.
1868 03 17	Puerto Rico	St. Thomas, Charlotte Amalie	0.6	An earthquake and tsunami were observed at Arroyo and Naguabo. At St. Thomas, Charlotte Amalie, there was a small recession and flooding.
1874 03 11	Lesser Antilles	Dominica Thomas, Virgin Is.		A submarine shock to the southeast of St. Thomas shook the island and ships in the harbor. Simultaneously, the water in the bay, then perfectly still, appeared turbid as though clouded by sand and mud. A little later strong ripples from the south agitated the water surface lasting some time. This probably was the tsunami and the earlier effects from the seismic waves agitating the bottom. At Dominica, the steamer Corsica reported a series of heavy rollers in the harbor lasting half an hour and rendering communication with the shore impossible. They did not feel the earthquake. The reduced effects at Charlotte Amalie may indicate a source on the eastern side of the island.
1881 09 12	Jamaica	Kingston, Jamaica	0.46	An earthquake was felt on the island and a wave was reported from the north coast. At Kingston Harbor, the water rose about 46cm. Berninghausen felt that this wave was not caused by the earthquake, but does not give any reason for his conclusion.
1882 09 07?	Panama	Northeastern Panama, San Bias Archipelago		Mine reports an earthquake for this date observed in Colombia, Panama, Nicaragua, and Ecuador but does not mention a tsunami. Camacho reported the tsunami but did not give details or a date.
1883 08 27	Indonesia	St. Thomas, Virgin Is.		A tidal wave occurred on August 27. The water receded from the shore three times. A sharp shock of an earthquake was felt on the following evening. This would have been an effect of Krakatoa Volcano eruption which created air waves widely recorded in Hawaii, Alaska, South Sandwich Islands, Great Britain, and elsewhere. The location of the Caribbean at near antipodal distances may have resulted in larger effects and these effects should have been observable through the islands. While these effects have been considered to not be true tsunamis elsewhere, this description sounds like a true tsunami was generated.

Annex I. Preliminary List of Historical Caribbean Tsunamis (continued)

Date	Area	Location of Effects	Runup(m)	Comments
1887	Haiti	Haiti: Mole Saint Nicholas, Anse-d'Hainault, & Pointe Tiburon		The epicenter was apparently near the Barlett Trough a short distance southwest from Mole Saint Nicholas. At Jeremie the sea withdrew 20m and returned with a rush. Waves were noted at Mole Saint Nicholas, Anse-d'Hainault, Pointe Tiburon, and other ports. Heck mistakenly identified the area as in the Philippines. Milne reports the earthquake felt at Port-de-Paix, Haiti and Inagua Island, Bahama Islands.
1907 01 14	Jamaica	Jamaica: Annotto Bay Hope Bay, Orange Bay, Sheerness Bay, Saint Anns Bay, Buff Bay Ocho Rios & Port Antonia	 7.1	Earthquake damage at Kingston and surrounding territory. Buff Bay was destroyed. Waves noted at Hope Bay, Orange Bay, Sheerness Bay, and Saint Anns Bay. At Annotto Bay, an observer reported the sea receded 73 to 93m, dropping 3 to 3.7m below normal sea level. The returning wave raised the water level 1.8 to 2.4m above normal, sweeping into the lower parts of town destroying house. On higher land it came up 7.6 to 9.1m. At Buff Bay the sea receded some distance from the land. At Port Maria the sea withdrew 25.6m At Ocho Rios near St. Anna Bay the sea withdrew 69m. At Port Antonia the wave moved a small building near the beach. Waves were also reported from the south coast of Jamaica and seiches were set up in Kingston Harbor.
1911 11 03	Trinidad	Trinidad		Some extraordinary waves were noticed on the coast following an explosion of a mud volcano island. This is a volcanic-related tsunami.
1916 04 25	Panama	Bocas del Toro, Panama		An earthquake was reported from Bocas del Toro and Alirante, and waves at Bocas del Toro carried debris and canoes 198m inland.
1918 10 11	Puerto Rico	Puerto Rico: Aguadilla Isabela Cayo Cardona El Bouqueron Punta Borinquen Isla Caja de uertos Gaunica Isla Mona Mayaguez Puerto Arecido Punta Agujereada Punta Higuero Rio Culebrinas St. Thomas: Charlotte Amalie & Krum Bay Santo Domingo, Hispaniola Tortola	 2.4-3.3 1.8 0.75 2.4 4.3 1.5 0.6 3.6 1.5 0.6 6.0 4.9 3.7 0.45 1.2 0.6	A magnitude 7.5 earthquake caused a wave of 2.4-3.3m above sea level at Aguadilla which destroyed 300 huts and drowned 34 people. At Cayo Cardona water rose 75cm on the west side of the island. At El Boqueron the wave dropped 1.5m and rose 90cm above mean sea level. About 800m southeast near the entrance to the bay the water rose only 45cm. At Punta Borinquen Lighthouse the wave was 4.5m above sea level. In a low area just southwest of the lighthouse the wave penetrated 91m inland. Submarine cables were cut in several places. At Gaunica, 45cm waves observed. At Isla Caja de Muertos water rose 1.5m covering 15m of the beach. At Isla Mona the receding water bared the reef and the returning wave was 3.6m above sea level washing a pier away and flooding a cistern. At Mayaguez, a wave entered the first floors of buildings near the waterfront and destroyed a few native huts and a brick wall was overturned. Water levels reached 40 to 150cm above sea level. At Playa Ponce slight water movements were observed. At Puerto Arecido, waves 30 to 60cm high were observed and a bore about 10c went up the Rio Grande. At Punta Agujereada, waves estimated at 5.5 to 6m uprooted several hundred palm trees and destroyed several small houses. Eight people drowned. At Punta Higuero Lighthouse waves uprooted coconut palms and crossed railroad tracks 4.9m above sea level while 800m southeast of the lighthouse the water rose 2.6 to 2.7m. At Rio Culbrinas, 1000kg blocks of limestone were moved 46 to 76m slightly downhill. Waves were at least 3.7 high. At Rio Grande de Lioza, water receded and rose about 90cm. At St. Thomas, Virgin Islands, Charlotte Amalie the water rose 45cm and at Krum Bay, 1.2m. At Santo Domingo, Hispaniola water of the Rio Ozama fell and rose 60cm with a period of 40 minutes. Waves were noted at Tortola.
1918 10 25	Puerto Rico	Puerto Rico, Mona Passage		Submarine cables were cut again and a steamer rolled heavily. Waves were recorded on the tide gage at Galveston, Texas.
1922 05 02	Puerto Rico			A wave was recorded on the Galveston gage which has been associated with a small earthquake in Viegues, but the small earthquake does not see likely to have produced a recordable tsunami.
1929 01 17	Venezuela	Cumana, Venezuela		City was destroyed by an earthquake and a steamer off shore was endangered by a huge wave. The tidal wave following the earthquake caused much damage. Many sailboats were wrecked.

Annex I. Preliminary List of Historical Caribbean Tsunamis (continued)

Date	Area	Location of Effects	Runup(m)	Comments

1932 02 03	Cuba	Santiago de Cuba		Small waves were reported at the time of an earthquake at Santiago de Cuba.
1946 09 04	Dominican Republic	Dominican Republic: Mantanzas Julia Molina & Samana San Juan, Puerto Rico Bermuda Daytona Beach, Florida Atlantic City, New Jersey	2.4	The town was severely damaged and 100 people killed although the wave probably was only 2.4m. At Villa Julia Molina the wave was estimated to be 3.6 to 4.6m high but caused little damage. At Cabo Samana several ebbs and flows were observed. It was recorded at San Juan, Puerto Rico, 36 minutes after the earthquake. It was also recorded at Bermuda at 2:07 after the earthquake and at Daytona Beach, 3:59 and Atlantic City, 4:49.
1946 09 08	Puerto Rico	Puerto Rico: Aquadilla Mayaguez & San Juan		The sea retreated 24m and returned. At Mayagues the sea retreated 76m and returned. At San Juan it was recorded on tide gauge 35 minutes after the earthquake. It was an aftershock of the August 4 event. The wave was also recorded with travel times of: Bermuda-2:02, Daytona Beach-4:02, and Atlantic City-4:42.
1953 05 31	Dominican Republic	Puerto Plata, Dominican Republic	0.6	Recorded on the Puerto Plata tide gage at 6cm height.
1955 01 18	Venezuela	Venezuela, La Vela		A wave was reported and four ships were wrecked and four waterfront buildings damaged. No earthquake is listed for this time.
1968 09 20	Venezuela			A report of a tsunami has not been verified.
1969 12 25	Leeward Is.	Barbados Antigua Dominica	0.14	Recorded at Barbados, Antigua, and Dominica with a maximum amplitude of 14cm at Barbados.
1985 03 16	Leeward Is.	Basse-Terre, Guadeloupe		A magnitude 6.3 earthquake at 14:54 GMT, caused damage and injuries to 6 people at Guadeloupe and minor damage at Montserrat. It was also felt at Antigua, St. Kitts, and Puerto Rico. A several cm tsunami was recorded at Basse-Terre, Guadeloupe.
1989 11 01	Puerto Rico	Cabo Rojo, Puerto Rico		A small tsunami was reported.
1991 04 22	Costa Rica	Bocas del Toro, Panama		At Bocas del Toro, Panama, people reported that Las Delicias sand bank normally covered by 60 to 90cm of water emerged as the sea receded less than ten minutes after the earthquake and remained above water for five to seven minutes. Afterwards several waves entered the bay with great force flooding 50 to 100m in the flat northern part of the town. At Carenero Island violent waves destroyed dwellings. At San Cristobal Island the sea receded several meters for about 45 minutes. People went on the beach to catch trapped fish. It was also observed at Bastimento, Cristobal-10cm, Puertobelo, W. Panama-60cm, and recorded at Colon.

ANNEX II. List of Seismic Stations in the Countries of the IAS Region*

CODE	NAME	COUNTRY	LAT	LONG	ELEV (m)	INSTRUMENT / TELEMETRY	INSTITUTION
OTAV	Otavalo	Imbaibura, Ecuador	0.238 N	78.451 W	3492		USGS/IRIS/Escuela Politecnica Nacional
PAYG	Puerto Ayora	Galapagos, Ecuador	0.6741 S	90.2863 W	196	Geotech KS-54000, CMG3-T, FBA all in borehole	USGS/IRIS/Escuela Politecnica Nacional
PAYV		Venezuela	5.5285 N	67.5468 W	91	CMG-40T, Satellite (Nanometrics)	FUNVISIS
BAUV		Venezuela	8.9433 N	68.0415 W	106	CMG-40T, Satellite (Nanometrics)	FUNVISIS
GUNV		Venezuela	10. 1617 N	62.9427 W	60	CMG-40T, Satellite (Nanometrics)	FUNVISIS
CRUV		Venezuela	10.6167 N	63.1833 W	608	CMG-40T, Satellite (Nanometrics)	FUNVISIS
TEST		Venezuela	10.4700 N	66.8100 W	875	CMG40T, Satellite (Nanometrics)	FUNVISIS
GUIV		Venezuela	10.647 N	62.223 W	50	CMG-40T, Satellite (Nanometrics)	FUNVISIS
BIRV		Venezuela	10.4757 N	66.2693 W	200	CMG-40T, Satellite (Nanometrics)	FUNVISIS
PTGA	Pitinga	Brazil	0.731 N	59.997 W	137		IRIS/USGS/Universidad de Brasilia
HDC2	Heredia 2	Costa Rica	10.0237 N	84.1167 W	1220	STS I	Observatorio Vulcanologico y Sismologico de Costa Rica, Universidad Nacional, Campus Omar Dengo, Heredia, Costa Rica
JTS	Juntas de Abangares	Costa Rica	10.2908 N	84.9525 W	340		IRIS-IDA; Observatorio Vulcanologico y Sismologico de Costa Rica, Universidad Nacional, Campus Omar Dengo, Heredia, Costa Rica
UNAH		Honduras	14.0750 N	87.1750 W	1020		Universidad Nacional Autonoma de Honduras
FDFZ		Martinique	14.7333 N	61.150 W	510		Observatoire de La Montagne Pelee, Institut de Physique du Globe
CUIG	Ciudad Universitaria	Mexico	19.329 N	99.178 W	2200		Instituto de Geophsica, Universidad Nacional Autonoma de Mexico
TEIG	Tepich	Yucatan, Mexico	20.2263 N	88.274 W	69		Instituto de Geophsica, Universidad Nacional Autonoma de Mexico
UPA	Universidad de Panama	Panama	8.9810 N	79.5338 W	41		Instituto de Geociencias, Universidad de Panama
GOGA	Godfrey	Georgia, USA	33.4112 N	83.4666 W	150		National Earthquake Information Center
OXF	Oxford	Mississippi, USA	34.5118 N	89.4092 W	101		National Earthquake Information Center
TUC	Tucson	Arizona, USA	32.3097 N	110.7842 W	906		National Earthquake Information Center
ANMO	Albuquerque	New Mexico USA	34.946 N	106.457 W	1740		USGS/IRIS
DWPF	Disney Preserve	Florida, USA	28.1110 N	8 1.433 W	-142	Deep Borehole	USGS/IRIS
HKT	Hockley	Texas, USA	29.950 W	95.833 W	-122	Salt Dome	USGS/University of Texas at Austin
JCT	Junction	Texas, USA	30.479 N	99.802 W	835		USGS/Texas Tech University
LRAL	Lakeview Retreat	Alabama, USA	32.8 N	86.9 W			USGS/Alabama Geological Survey
LTX	Lajitas	Texas, USA	29.334 N	103.667 W	1013		USGS
MIAR	Mt. Ida	Arkansas, USA	34.546 N	93.573 W	207		USGS
NHSC	New Hope	South Carolina, USA	33.107 N	80.178 W	12		USGS
PLAL	Pickwick Lake	Alabama, USA	34.982 N	88.076 W	165		USGS/St. Louis University
WMOK	Wichita Mountain	Oklahoma, USA	34.738 N	98.781 W	486		USGS
SDV	Santo Domingo	Venezuela	8.8861 N	70.6333 W	1580		CAR (FUNVISIS), IRIS-USGS

IMO	Isla Mona	Isla Mona, Puerto Rico	18.111 N	67.908 W	50	CMG-40T, UHF and DDS comm to Central	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez
AGP	Aguadilla	Puerto Rico	18.4075 N	67.141 W	220	CMG-3ESP, FBA, UHF and DDS comm to Central	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez
CORN	Cornellia Hill	Cabo Rojo, Puerto Rico	18.163 N	67.179 W	100	CMG-40T, FBA, on site recording	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez
MGP	Maguayo	Lajas, Puerto Rico	18.007 N	67.089 W	60	CMG-40T, UHF and DDS comm to Central	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez
CDP	Cerro de Punta	Jayuya, Puerto Rico	18.175 N	66.591 W	1300	CMG-40T, FBA, Microwave and DDS comm to Central	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez
SJG	Cayey	Puerto Rico	18.1117 N	66.1500 W	457	STS-I/VBB	IRIS-USGS
ICMB	Isla Caja De Muertos	Puerto Rico				CMG-40, UHF and DDS comm to Central	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez
CPD	Cerro Pandura	Yabucoa, Puerto Rico	18.037 N	65.9147 W	370	CMG-40T, UHF and DDS comm to Central	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez
CBYP	Cubuy	Canovanas, Puerto Rico	18.275 N	65.8605 W	140	CMG-40T, FBA, UHF and DDS comm to Central	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez
MTP	Monte Pirata	Vieques, Puerto Rico	18.0847 N	65.5525 W	300	CMG-40T, UHF and DDS comm to Central	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez
CULB	Monte Resaca	Culebra, Puerto Rico				CMG-40T, FBA, UHF and DDS comm to Central	Puerto Rico Seismic Network, Univ. of Puerto Rico at Mayaguez

* Only 3 stations, SJG, HDC2, and PAYG, have a frequency response compatible with TREMORS. In addition, the TREMORS software requires the data to be in mini-SEED or GSE2.1 format.

Annex III. IOCARIBE Regional GLOSS: Sea-Level / Weather Coastal Stations

Country / Site	Latitude (north)	Longitude (west)	Sponsor	Gauge Type	Trans-mission	GPS	Ancillary Sensors
Antigua & Barbuda: Parham	17° 09' 30"	61° 47' 20"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Aruba: Sint Nicolas	12° 26'	69° 54'	IOC/UNEP	Pressure	None	No	None*
Bahamas: Lee Stocking Island	23° 46' 24"	76° 06' 20"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Great Inagua	21° 03' 07"	73° 38' 47"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Nassau	25° 05' 10"	77° 22' 06"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Settlement Point	26° 30'	78° 46'	NOAA	Acoustic	GOES	Yes	Met., SST
Barbados: Bridgetown	13° 06' 06"	59° 37' 42"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Belize: Belize City	17° 28' 51"	88° 12' 08"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Bermuda: St. Georges	32° 23'	64° 41'	UK	Pressure	None	No	None
Cayman Islands: Georgetown	19° 18'	81° 26'	UK	Float	None	No	None
Colombia: Cartagena	10° 19'	75° 35'	NOAA	Float	None	No	None
Costa Rica: Puerto Limon	10° 00'	83° 01'	Finland	Pressure	GOES	Yes	Met., SST
Cuba: Cabo San Antonio	21° 52'	84° 57'	National	Float	None	No	None
Gibara	21° 07'	76° 07'	National	Float	None	No	None
Guantanamo Bay	19° 54.4'	75° 08.9'	IOC/UNEP	Acoustic	GOES	Yes	None*
Siboney	23° 09'	82° 21'	National	Float	None	No	None
Dominica: Roseau	15° 18' 20"	61° 23' 42"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Dominican Republic: Puerto Plata	19° 49'	70° 41'	National	Bubbler	None	No	None
Barahona	18° 11'	71° 07'	National	Bubbler	None	No	None
France: Cayene	4° 56'	52° 20'	National	Float	None	No	None
Kourou	5° 12'	52° 39'	National	Pressure	None	No	None
Fort-de-France	14° 36	61° 05'	National	Float	None	No	None
Basse Terre	16° 00'	61° 44'	National	Float	None	No	None
Grenada: Prickly Bay	12° 00' 20"	61° 45' 56"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Guatemala: Santo Tomas de Castilla	15° 41.7’	88° 37.2’	RONMAC	Acoustic	GOES	Yes	Met., SST
Guyana: Georgetown	6° 48.5'	58° 10.5'	IOC/UNEP	Acoustic	GOES	Yes	None
Rosignol	6° 18' 15"	57° 30' 45"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Parika	6° 50' 48"	58° 23' 06"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Honduras: Cochino Pequeño	15° 57' 09"	86° 29' 56"	Smithsonian	Acoustic	GOES	Yes	Met., SST
Puerto Cortes	15° 50.1′	87° 57.2′	RONMAC	Acoustic	GOES	Yes	Met., SST
Jamaica: Discovery Bay	18° 28' 06"	77° 25' 00"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Kingston	17° 56' 54"	76° 50' 42"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Mexico: Progresso	21° 17'	89° 40'	National	Float	None	No	None
Puerto Morelos	20° 50'	86° 52'	NOAA	Float	None	No	None
Tampico	22° 13'	97° 51'	National	Float	None	No	None
Veracruz	19° 12'	96° 08'	National	Float	None	No	None
Netherlands Antilles: Curaçao	12° 07'	68° 56'	National	Float	None	No	None
Nicaragua: Puerto Cabezas	14° 01.2′	83° 22.9′	RONMAC	Acoustic	GOES	Yes	Met., SST
Panama: Coco Solo (Limon Bay)	9° 22'	79° 54'	Canal Zone	Pressure	None	No	None
St. Kitts & Nevis: Basse Terre	17° 17' 24"	62° 42' 36"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
St. Lucia: Castries	14° 01' 20"	61° 00' 06"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
St. Vincent: Kingstown	13° 07' 50"	61° 11' 55"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Trinidad & Tobago: Charlotteville	11° 19' 25"	60° 32' 55"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Guayaguayre	10° 08' 20"	61° 00' 06"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Port-of-Spain	10° 38' 56"	61° 30' 51"	GEF/OAS	Acoustic	GOES	Yes	Met., SST
Turks&Caicos: South Caicos	21° 30'	71° 31'	IOC/UNEP	Acoustic	GOES	No	Met., SST*
USA: Fernandina Beach	30° 40'	81° 27'	National	Acoustic	GOES	Yes	Met., SST
Miami (Virginia Key)	25° 47'	80° 11'	National	Acoustic	GOES	Yes	Met., SST
Key West	24° 33'	81° 49'	National	Acoustic	GOES	Yes	Met., SST
Naples	26° 10'	81° 48'	National	Acoustic	GOES	Yes	Met., SST
Clearwater Beach	27° 57'	82° 48'	National	Acoustic	GOES	Yes	Met., SST
Cedar Key	29° 08'	83° 06'	National	Acoustic	GOES	Yes	Met., SST
Pensacola	30° 24'	87° 13'	National	Acoustic	GOES	Yes	Met., SST
Grand Isle	29° 14'	89° 59'	National	Acoustic	GOES	Yes	Met., SST
Galveston Pier 21	29° 19'	94° 47'	National	Acoustic	GOES	Yes	Met., SST
Port Isabel	26° 05'	97° 16'	National	Acoustic	GOES	Yes	Met., SST
San Juan PR	18° 28'	66° 07'	National	Acoustic	GOES	Yes	Met., SST
La Parguera PR	17° 59'	67° 03'	National	Acoustic	GOES	Yes	Met., SST
Lime Tree Bay USVI	17° 42'	64° 45'	National National	Acoustic	GOES	Yes	Met., SST
Charlotte Amalie USVI	18° 21'	64° 54'	National National	Acoustic	GOES	Yes	Met., SST
Venezuela: Cumana	10° 25'	64° 17'		Float	None	No	None
La Guaira	10° 37'	66° 56'		Float	None	No	None

*Out of Order

Annex IV. Recommended IAS TWS Sea Level Stations

Country / Site	Latitude (North)	Longitude (West)	Sponsor	Gauge Type	Tsunami Upgrade
Bahamas: Lee Stocking Island	23° 46' 24"	76° 06' 20"	GEF/OAS	Acoustic	$5000
Settlement Point	26° 30'	78° 46'	NOAA	Acoustic	$5000
Barbados: Bridgetown	13° 06' 06"	59° 37' 42"	GEF/OAS	Acoustic	$5000
Belize: Belize City	17° 28' 51"	88° 12' 08"	GEF/OAS	Acoustic	$5000
Bermuda: St. Georges	32° 23'	64° 41'	UK	Pressure	$5000
Cayman Islands: Georgetown	19° 18'	81° 26'	UK	Float	$8000
Colombia: Cartagena	10° 19'	75° 35'		Acoustic	$35000
Isla de San Andres	12.5°	81.8°		Pressure	$8000
Costa Rica: Puerto Limon	10° 00'	83° 01'	Finland	Pressure	$5000
Cuba: Cabo San Antonio	21° 52'	84° 57'		Acoustic	$35000
Guantanamo Bay	19° 54.4'	75° 08.9'		Acoustic	$35000
Dominican Republic: Barahona	18° 11'	71° 07'	National	Bubbler	$8000
France: Fort-de-France	14° 36'	65° 05'	National	Float	$8000
Honduras: Puerto Cortes	15.9°	88.0°	RONMAC	Acoustic	$0
Swan Island	17.4°	83.8°		Pressure	$8000
Jamaica: Kingston	17° 56' 54"	76° 50' 42"	GEF/OAS	Acoustic	$5000
Mexico: Puerto Morelos	20° 50'	86° 52'		Acoustic	$35000
Veracruz	19° 12'	96° 08'	National	Float	$8000
Netherlands Antilles: Curaçao	12° 07'	68° 56'	National	Float	$8000
St. Martin	18.1°	63.2°		Acoustic	$35000
Nicaragua: Puerto Cabezas	14.1°	83.6°	RONMAC	Acoustic	$0
Panama: Coco Solo	9° 22'	79° 54'		Acoustic	$35000
Trinidad & Tobago: Charlotteville	11° 19' 25"	60° 32' 55"	GEF/OAS	Acoustic	$5000
USA: Key West	24° 33'	81° 49'	National	Acoustic	$3000
Clearwater Beach	27° 57'	82° 48'	National	Acoustic	$3000
Grand Isle	29° 14'	89° 59'	National	Acoustic	$3000
Galveston Pier 21	29° 19'	94° 47'	National	Acoustic	$3000
Port Isabel	26° 05'	97° 16'	National	Acoustic	$3000
San Juan PR	18° 28'	66° 07'	National	Acoustic	$3000
Venezuela: Isla de Aves	15.7°	63.6°		Pressure	$8000
La Blanquilla	11.8°	64.7°		Pressure	$8000