COASTAL HAZARD EARLY WARNING SYSTEMS IN PAKISTAN: GAP ANALYSIS

Tsunami and Cyclone Early Warning Dissemination: Gaps and capacities in coastal areas of Balochistan and Sindh Provinces

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If a large earthquake were to occur off the coast of Pakistan and trigger a tsunami, residents of fishing villages would need to act quickly in order to escape. A tsunami caused by an earthquake in this region in November 1945 claimed hundreds of lives. Most of the fatalities occurred along tidal creeks of the Indus River Delta, where people scarcely felt the original earthquake. Today, many of the villages in the Delta can still only be reached by boat, and telecommunications are limited. These circumstances add to the challenge of alerting local people to the danger of any incoming tsunami.

This study, supported by Oxfam GB, underlines the extent of this challenge. It analyses the limitations of early warning dissemination systems in the coastal belt of Pakistan and investigates opportunities for strengthening them. It highlights the vulnerability of coastal communities in the face of natural hazards such as tsunamis and cyclones, due to their isolation, the limitations of communications infrastructure and limited awareness and preparedness of local authorities.

CONTENTS

ACRONYMS AND ABBREVIATIONS

AHD	Association for Humanitarian Development
dB	Decibel
DCO	District Coordination Officer
DDMA	District Disaster Management Authority
DRM	Disaster risk management
DRR	Disaster risk reduction
EWS	Early warning system
FGD	Focus group discussion
GPA	Gwadar Port Authority
GSM	Global System for Mobile Communications
HF/VHF	High frequency/very high frequency
IOC-UNESCO	Intergovernmental Oceanographic Commission of UNESCO
IOTIC	Indian Ocean Tsunami Information Center
IRC	Indus Resource Centre
KII	Key informant interview
KPT	Karachi Port Trust
MSZ	Makran Subduction Zone
NDMA	National Disaster Management Authority
NRSP	National Rural Support Programme
SMETWC	Seismic Monitoring and Early Tsunami Warning Centre
PCG	Pakistan Coast Guards
PTWC	Pacific Tsunami Warning Center
PMD	Pakistan Meteorological Department
PDMA	Provincial Disaster Management Authority
PMSA	Pakistan Maritime Security Agency
RCDC	Rural Community Development Council
SOP	Standard operating procedure
TCCR	Trust for Conservation of Coastal Resources
TCP/IP	Transmission Control Protocol/Internet Protocol
TEWS	Tsunami Early Warning Systems
UNDP	United Nations Development Programme
WWF	World Wide Fund for Nature

SUMMARY

If a large earthquake were to occur in the volatile Makran Subduction Zone (MSZ) off the coast of Pakistan and trigger a tsunami, residents of local fishing villages would need to act quickly in order to escape. A tsunami caused by an earthquake in the MSZ in November 1945 claimed hundreds of lives. Most of the fatalities occurred along tidal creeks of the Indus River Delta, where people scarcely felt the original earthquake. Today, many of the villages in the Delta can still only be reached by boat, and telecommunications are limited. These circumstances add to the challenge of alerting local people to the danger of any incoming tsunami. Time is much more limited than in the case of cyclones, where communities may have 2–3 days' warning rather than hours or minutes.

This study, supported by Oxfam GB, underscores the extent of this challenge. It analyses the limitations of early warning dissemination systems in the coastal belt of Pakistan and investigates opportunities for strengthening them. It highlights the vulnerability of coastal communities in the face of natural hazards such as tsunamis and cyclones, due to their isolation, the limitations of communications infrastructure and limited awareness and preparedness of local authorities.

The report is based on field surveys carried out in 10 selected villages in four coastal districts in Sindh and Balochistan provinces, including focus group discussions, household surveys and informal interactions with community members and other important stakeholders in each community, together with a literature review of the capacities and disaster management protocols of key authorities.

Data analysis of the field surveys shows that coastal villages have limited links to official warning systems through means such as landlines, mobile phones and the Internet. Only one of the villages surveyed has access to landline telephones and none has access to satellite phones, while GSM coverage is limited in many communities. The organizations responsible for generating and disseminating coastal hazard early warnings use all of these communication networks to relay information. However, currently the only method used to communicate this information over the final mile to remote coastal communities is notification in person, with officials physically travelling to the location to relay warnings.

The Pakistan Coast Guards (PCG) have a considerable presence along the coastline and the agency's coastguard posts could be used to effectively disseminate information via its high frequency/very high frequency (HF/VHF) radio network, as well as personal notifications in combination with other types of notification system. In communities where dissemination is not possible via PCG posts (e.g. Sirki and Sonth villages in Gwadar), satellite-activated mass notification systems (using, for example, Inmarsat satellite systems to activate sirens) and satellite phones could be an effective channel.

The report also discusses the standard operating procedures (SOPs) adopted by the authorities responsible for the dissemination of coastal hazard early warnings and for emergency response and disaster management. It discusses their limitations both in relaying warnings and in responding to an emergency, such as the lack of appropriate means – such as boats and helicopters – to cover the last mile in difficult-to-access coastal areas. If an earthquake hits the area, it may be less than half an hour before a tsunami strikes. The report provides specific recommendations to improve the dissemination of early warning information and the management of risk. As well as technical solutions, these address land use management, training of communities, research and database development, a clearer delineation of responsibilities by coordinating SOPs amongst stakeholder agencies and enhancing the capacity of the media to convey early warnings.

1 BACKGROUND

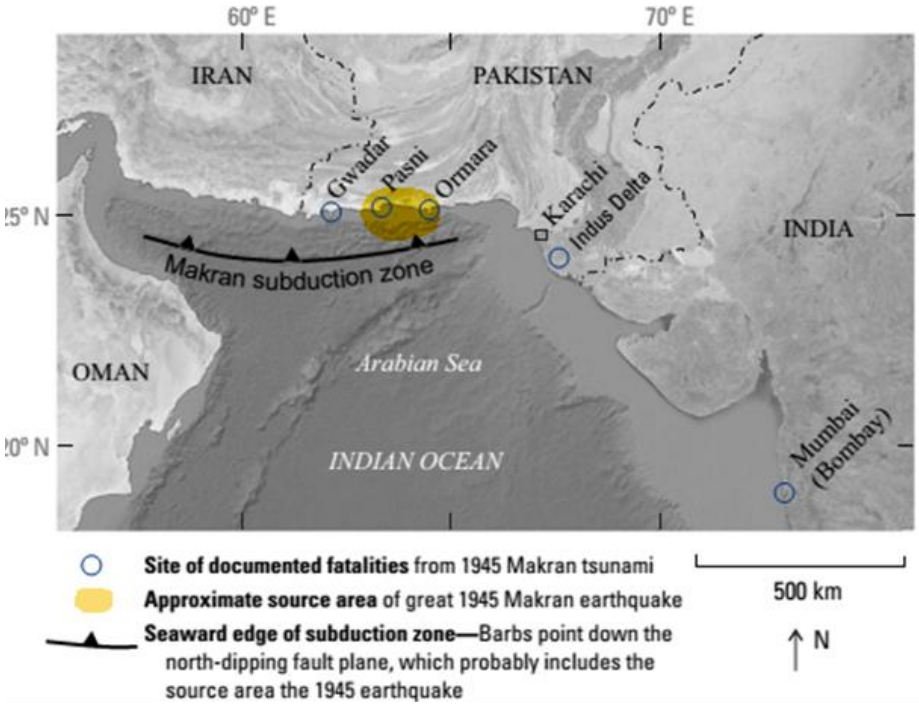
The coast of Pakistan has a varied topography that includes sandy beaches, headlands, mudflats, rocky cliffs, bays and deltas. The climate along the northern coastlines of the Arabian Sea is arid to semi-arid. Tropical cyclones affect the coastlines of Pakistan and India more frequently than the coasts of Oman and Iran; however, the latter coastlines were severely affected by cyclones Gonu and Phet, in 2007 and 2010 respectively.[1]

Of the country's 1,150 kilometres of coastline, more than 600km lies within Balochistan province, with the remainder in Sindh province. On the Balochistan coast, the population is concentrated mostly in port cities such as Gwadar and Pasni, smaller towns such as Ormar, Jiwani, Daam and Sonmiani and scattered villages. Sindh has a variety of towns and small cities on the coast and along the creeks of the Indus Delta, as well the metropolitan city of Karachi, which has over 22 million inhabitants.

Pakistan's National Disaster Management Authority (NDMA)[2] has identified tsunamis and cyclones originating in the northern Indian Ocean as key threats to the Sindh and Balochistan coastal belts.[3] The coastline lies along the Makran Subduction Zone (MSZ), an active boundary between converging tectonic plates that descends northward beneath Iran and Pakistan. Seismic activity in the zone means that populations are exposed to a high risk of earthquakes and tsunamis.[4] In November 1945 an earthquake with a magnitude of 8.1 on the Richter scale generated a tsunami that struck the coasts of Pakistan, India, Iran and Oman. Balochistan, especially the Makran coast, was severely affected, with waves 12–15 metres high claiming hundreds of lives and possibly as many as 4,000.

The small fishing communities scattered along the Makran coastal strip (which extends into neighbouring Iran) and the coast of Sindh are particularly vulnerable to tsunami and cyclone hazards, with climate change amplifying the cyclone risk considerably. The port city of Gwadar, which has a population of 85,000 and where major infrastructure developments are planned, is also extremely vulnerable to the risk of tsunamis.[5] In Sindh, the towns of Badin and Thatta are under serious threat from rising sea levels and water intrusion.

Figure 1: Makran and Indus Delta creek region affected by the 1945 tsunami; the same area is studied in the present report.



Source: Kakar et al. (2014).

The MSZ makes this one of the most geo-seismically vulnerable regions of Pakistan and, to protect people at high risk, there is an urgent need for mitigation strategies. The first priority for hazard risk reduction, mitigation and preparedness should be an efficient multi-hazard early warning system (EWS). Given the limited time available for reaction in the case of a local tsunami (see below), the only way to safeguard the coastal population is pre-tsunami preparedness. This requires an assessment of the potential tsunami hazard, which involves three important components: tsunami awareness, early warning and evacuation planning. There is an urgent need to strengthen EWS for hazards such as tsunamis and cyclones, particularly in the remote coastal areas of Makran and Sindh, where the communities most at risk generally lack basic communication facilities such as television sets, landlines and cellular phones.

Establishing multi-hazard EWS and/or strengthening existing systems will help to protect communities from tsunamis, cyclones and storms and will also enable emergency response agencies to respond more efficiently. Timely warning of danger would alert fishermen (the dominant livelihood occupation in these coastal communities) to return to shore and would give the whole community a chance to evacuate inland.[6]

Risk assessment provides essential information to set priorities for mitigation, prevention and preparedness strategies and for the design of EWS. EWS that incorporate effective monitoring and prediction capabilities can provide timely estimates of the potential risk faced by communities, economies and the natural and built environments. Timely dissemination of information demands effective and efficient communication systems to deliver warning messages to at-risk populations and to alert local and regional governmental agencies. Messages need to be clear and easy to understand for both authorities and the general public. Coordination, good governance and appropriate action plans are key factors in building an effective early warning dissemination system. General public awareness and education are also critical aspects of disaster prevention and mitigation. If any part of this system fails, then the whole system will fail.

This study was commissioned by Oxfam GB to examine the potential for improving and expanding EWS in the coastal areas of Sindh and Balochistan, looking at both structural and non-structural components and mechanisms. It also looks at the capacity of relevant authorities in the two provinces, reviewing their existing policies and procedures, structures and functions, reporting and response mechanisms and limitations and gaps in capacity, in particular gaps in relaying crucial information over the final mile to communities.

This report analyses the gaps in Pakistan's coastal hazard EWS, in particular gaps relating to the dissemination of information to coastal communities. EWS generally comprise two components, the detection of threat and the subsequent relaying of information; this report focuses only on the latter. Due to limitations in infrastructure, knowledge management and awareness among citizens, warnings are rarely delivered to communities in time, increasing the vulnerability of already poverty-stricken residents of coastal areas. The report looks in particular at the challenges involved in communicating early warnings of near-source tsunamis in the smallest available reaction time. It provides an overview of current arrangements for relaying warnings and of the limitations of current systems, with reference to a sample of villages along the coast. It then makes recommendations for improvements to the current system, with responsibilities shared among a range of stakeholders.

2 INTRODUCTION

Recent cyclone events – Cyclone Gonu in 2007 and Cyclone Phet in 2010 – and the deadly tsunamis in the Indian Ocean in 2004 and off the coast of Japan in 2011 have provided a wake-up call for the scientific community and for developers, planners and decision makers to prepare for a worst-case scenario. Moreover, as a result of unplanned urban growth, negligence of construction standards, localized concentration of populations and infrastructure and a lack of awareness both amongst the public and at institutional level, coastal communities in developing countries are more vulnerable than ever to the adverse effects of seismic and climatic hazards. Tsunamis and cyclones involve complex risks and have the potential to cause massive damage.

Historical and geological evidence of tsunamis along the shores of the Arabian Sea in the Northern Indian Ocean is sparse and in some cases contradictory. The 1945 Makran earthquake is the only one known to have generated a tsunami that was scientifically recorded, and this event therefore serves as the basis for modelling approaches.[7] Numerical analysis and modelling are used as the basis for tsunami and cyclone early warning systems (EWS), which have recently been set up in the region.[8]

The Early Tsunami Warning Center and the Tropical Cyclone Warning Center have been set up by the Pakistan Meteorological Department (PMD) to monitor, investigate and warn about tsunami and cyclone threats to the country's coastline. Under a set of standard operating procedures (SOPs), the PMD categorizes tsunamis into different types based on the magnitude of an earthquake and the location of its epicentre.[9] A 'local tsunami' is one that can occur after an earthquake with a magnitude of 7.0–7.5 on the Richter scale and is destructive within a radius of 100km of the epicentre. A 'regional tsunami' can occur after an earthquake with a magnitude of 7.6–7.9 and is destructive within a 1,000km radius of the epicentre. An 'ocean-wide tsunami' can be triggered by an earthquake of 8.0 or above and its life-threatening effects can span the entire ocean.

A regional or local tsunami – such as the Makran event in the Arabian Sea in 1945 – is potentially more destructive for Pakistan's coastal belt than one originating further out in the Indian Ocean, as there is much less time to evacuate. Usually a potential threat of tsunami is associated with earthquakes of magnitude 6.5 and above, and warnings for local tsunamis should be issued to communities within 7–10 minutes of an earthquake happening. A tsunami originating far out in the Indian Ocean might take as long as 10–13 hours to reach the coast of Pakistan; therefore tsunami warnings are issued only if an earthquake has a magnitude of 7.0 or above.[10]

METHODOLOGY

The study methods included a desk review of available documents and data on the subject, the collection and analysis of data from primary and secondary sources, direct field observations and interviews with community representatives and personnel from preparedness and response agencies. The information gathered was summarized and analysed to identify issues and gaps and to develop recommendations on effective early warnings for coastal communities.

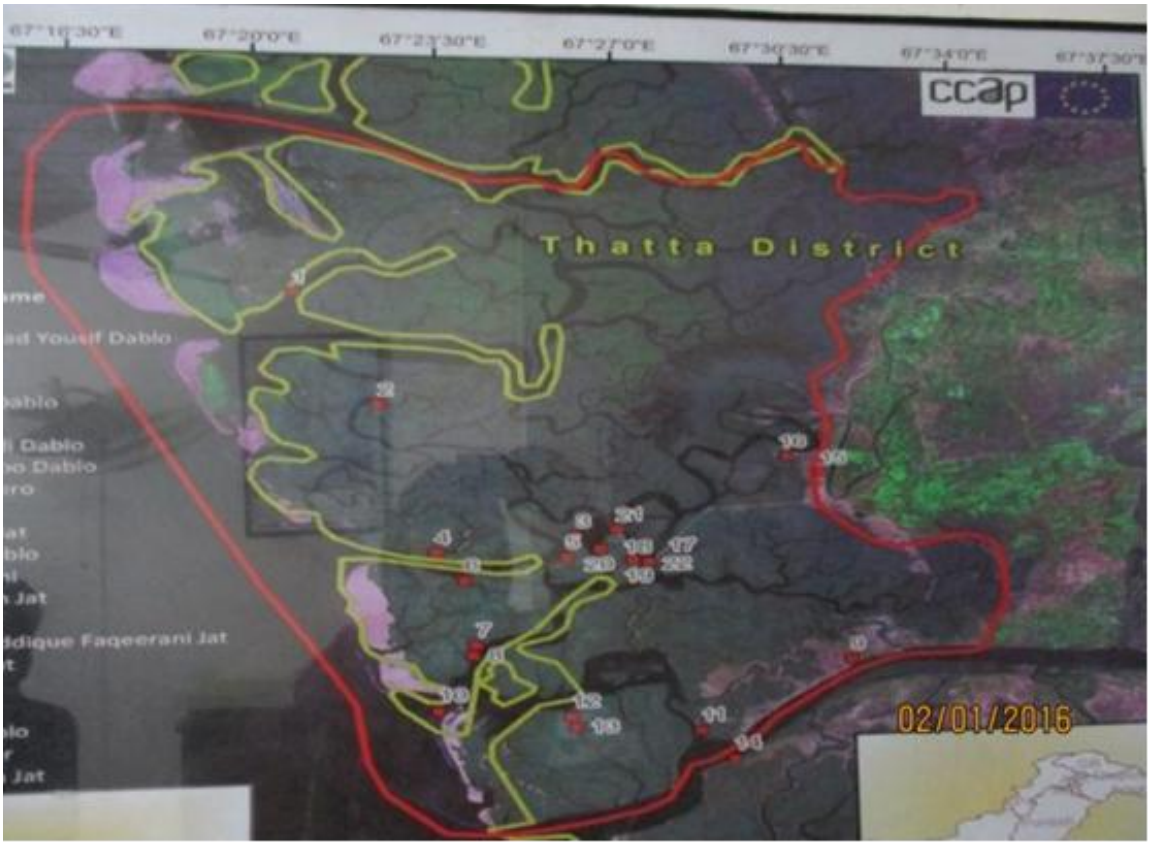
Secondary data collection

A desk review was conducted, comprising a thorough review of previous reports and relevant literature, including *Standard Operating Procedures for Tusnami Tsunami Warning* by the Seismic Monitoring and Early Tsunami Warning Center at the PMD (2010), *Tsunami Risk Reduction for the Coastal Areas of Pakistan* by the National Disaster Management Authority (NDMA), reports from the United Nations Development Programme (UNDP)'s pioneering project

'Strengthening Tsunami Early Warning Systems (TEWS) in Pakistan', the project website *1945 Makran Tsunami* by the Indian Ocean Tsunami Information Center (IOTIC) and the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) and policy documents of various government organizations to understand the missions and objectives of different stakeholders.

Data relating to the geography, topography and demography of the target areas were collected from Deputy Commissioner offices, WWF-Pakistan, Google imagery and a survey of maps of the area.

Figure 2: The areas outlined in yellow on the map indicate field visits conducted in Thatta District around Keti Bandar



Source: WWF-Pakistan Gharo Office

Primary data collection

Primary data collection was conducted via a field survey comprising three main parts: household interviews, key informant interviews (KIIs) and focus group discussions (FGDs). The research team, led by the principal investigator, visited 10 villages in Thatta, Sujawal and Badin Districts of Sindh province and Gwadar District in Balochistan (see Table 1). The team was assisted by representative of the communities they visited, who interpreted and translated questions and answers for both parties.

Table 1: Areas visited in Sindh and Balochistan

Sindh Province	*Thatta District*	**Phirt Creek**
		Tippun Creek
		Khobar Creek
		Bhori Creek
	Sajawal District	Rohro Creek
		Haji Yousuf Goth
	Badin District	Peer Sheikh Prio
		Goth Ramzan Sheikh
Balochistan Province	*Ormara tehsil, Gwadar District*	Sonth Village
		Sirki Village

Household interviews

A detailed outline was developed for household interviews, focusing primarily on existing infrastructure for early warning communication systems in the communities, their efficacy in delivering information and warning people at risk in times of disaster (from tsunamis and cyclones) and constraints or limitations observed in their operation.

Left: Interviewing **community** elder M Somar at Somar Dablo Village, Phirt Creek, Sindh. Right: Kamal-ud-Din, resident of Sirki Village, Gwadar also witnessed 1945 tsunami

Key informant interviews

The research team consulted and interviewed officials and field staff of non-governmental organizations – WWF-Pakistan, the Rural Community Development Council (RCDC) in Gwadar, the Trust for Conservation of Coastal Resources (TCCR) in Sindh – and government organizations including the PMD, the Pakistan Navy and the Government of Sindh. Their observations, suggestions and recommendations have been incorporated into this document.

Focus group discussions

Questions concerning EWS and the 1945 tsunami were put mostly to middle-aged and elderly men (mostly fishermen by occupation) and women from different households. A special emphasis was placed on the availability of different systems of communication in the community. An additional part of the investigation involved recording oral histories of the 1945 tsunami. For this purpose, the researchers asked senior household members to recount what they had observed or heard.

Left: Focus group discussion in Keti Bandar. Right: Group discussion with locals at a clinic in Kharo Chan, which has not been operational for the past five years

Compilation and analysis

The data collected from site visits, KIIs and FGDs were compiled and evaluated to draw conclusions on the current situation and to inform recommendations for actions that would help to eliminate gaps and improve the systems currently in use for early warning communications.

A WWF boat and social mobilizers were engaged for the mission to the Indus creek system at Keti Bandar and Kharo Chan. Volunteer Abdullah Usman of the RCDC also accompanied the team

3 THE CURRENT SITUATION

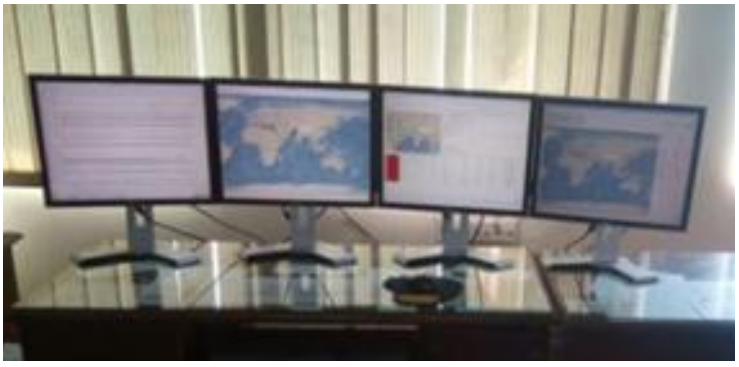
Institutional arrangements for disaster management

The 2004 Indian Ocean tsunami and the 2005 Kashmir earthquake prompted the Pakistani authorities to put in place institutional arrangements for disaster management and to strengthen existing early warning dissemination systems that could relay warnings to those most at risk. In March 2010 the Seismic Warning and Early Tsunami Warning Center (SWETWC) at the Pakistan Meteorological Department published a set of standard operating procedures (SOPs) for tsunami warning. It identified the PMD, disaster management authorities and emergency responders as the key actors within the early warning communication chain, which begins with the SWETWC and ends with the communities at risk. Early warning of cyclones is usually received 3–4 days before they make landfall and information is disseminated effectively to communities, remote ones as well as the more accessible; the same institutional arrangements are used for early warning of tsunamis. This section assesses the institutional arrangements of the key authorities in terms of their capacities and limitations. They fall into into two separate categories: early warning dissemination agencies and emergency responders.

3.1 EARLY WARNING DISSEMINATION AGENCIES

Pakistan Meteorological Department

The SWETWC of the PMD, based in Karachi, is equipped to issue warnings based on data from real-time monitoring of seismic activity by national and global networks in order to identify potentially tsunamigenic earthquakes. It is also in contact with the Pacific Tsunami Warning Center (PTWC)[11] and the Japan Meteorological Agency (JMA)[12] to monitor information on the Indian Ocean. When a warning is received, the SWETWC assesses it and communicates a message to the local-level District Disaster Management Authorities (DDMAs). Similarly, the PMD's Tropical Cyclone Warning Center receives warnings from national and global sources.



The NSMTEWC established at PMD Karachi is connected to national and international networks and is operational on 24-hour basis.

The PMD has SOPs in place on the format of bulletins, based on the category of tsunami threat. Bulletins should include information on the level of threat, the name of the issuing agency, the time of issue and earthquake parameters (location, magnitude and depth). For cyclones, it issues updates on the category of cyclone and its path, etc.

The PMD sends out this information via multiple communication channels, including:

- Automated GPRS-based SMS text messages
- Mobile phone-based SMS text messages (back-up)
- Automated fax – two channels
- Manual fax – one channel
- Satellite telephone
- Updates to its website www.pmdnmcc.net/seismic/index.asp
- Email.

Although SMS is normally an effective mode of communication, in times of emergency it can be unreliable. It is a linear mode of communication that cannot confirm whether the message has been received; in addition, people frequently change their cellphone numbers.

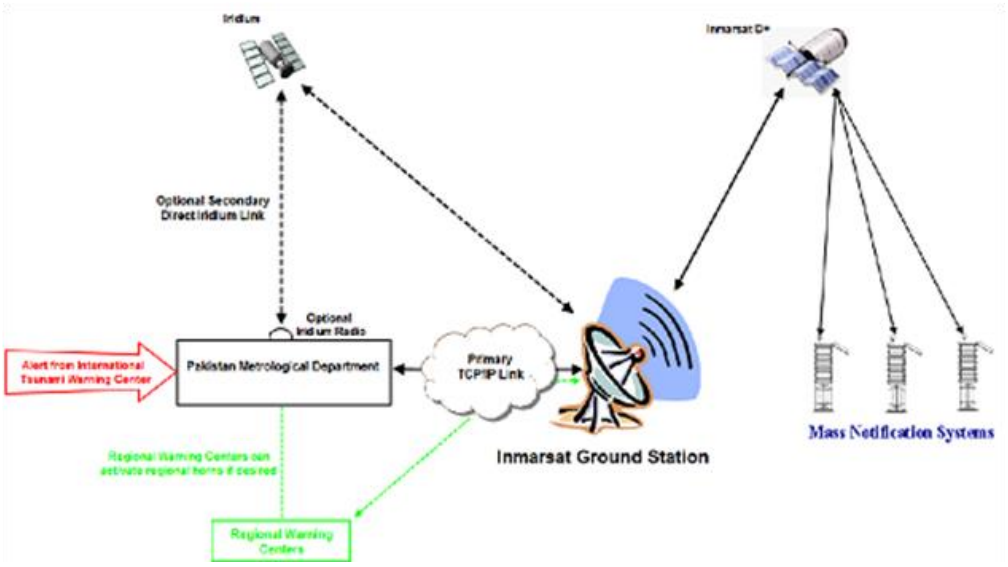
Information flow

The PMD is the key focal agency for early warning of coastal hazards, and handles all initial information flows on tsunamis and cyclones. According to its (expected) information flow plan, any information it receives about the possibility of a natural disaster from national or international sources is first conveyed to response agencies and stakeholders at the national, provincial and district levels:

- the NDMA
- the Provincial Disaster Management Authorities (PDMAs) for Balochistan and Sindh
- District Coordination Officers (DCOs) for Karachi, Gwadar, Lasbela, Thatta, Sujawal and Badin districts
- Pakistan Army and Navy
- Pakistan Coast Guards
- Pakistan Maritime Security Agency (PMSA)
- Karachi Port Trust (KPT)
- Gwadar Port Authority (GPA).

The PMD disseminates this information using the modes of communication listed above (see Figure 4). In addition, it has recently installed mass notification systems in the cities of Gwadar and Pasni, which are connected via satellite to the PMD office in Karachi and can be directly activated using a satellite link. The PMD sends a tsunami warning message to an Inmarsat ground station, using TCP/IP – essentially an Internet link. The ground station relays this signal to an Inmarsat satellite, which then activates sirens in Pasni and Gwadar. Notifications can also be sent via regional warning centres. The main elements of the system are shown in Figure 3.

Figure 3: Inmarset Siren system (at Gwadar & Pasni) are activated through satellite connection from PMD Tsunami Center Karachi



Though the primary link between the PMD and the Inmarsat service is TCP/IP, the system's redundancy and reliability could be increased by using a secondary direct link via the Iridium satellite network, with an Iridium radio set installed at PMD Karachi.

Figure 4: The PMD's timeline for processing and dissemination of tsunami bulletins for the MSZ

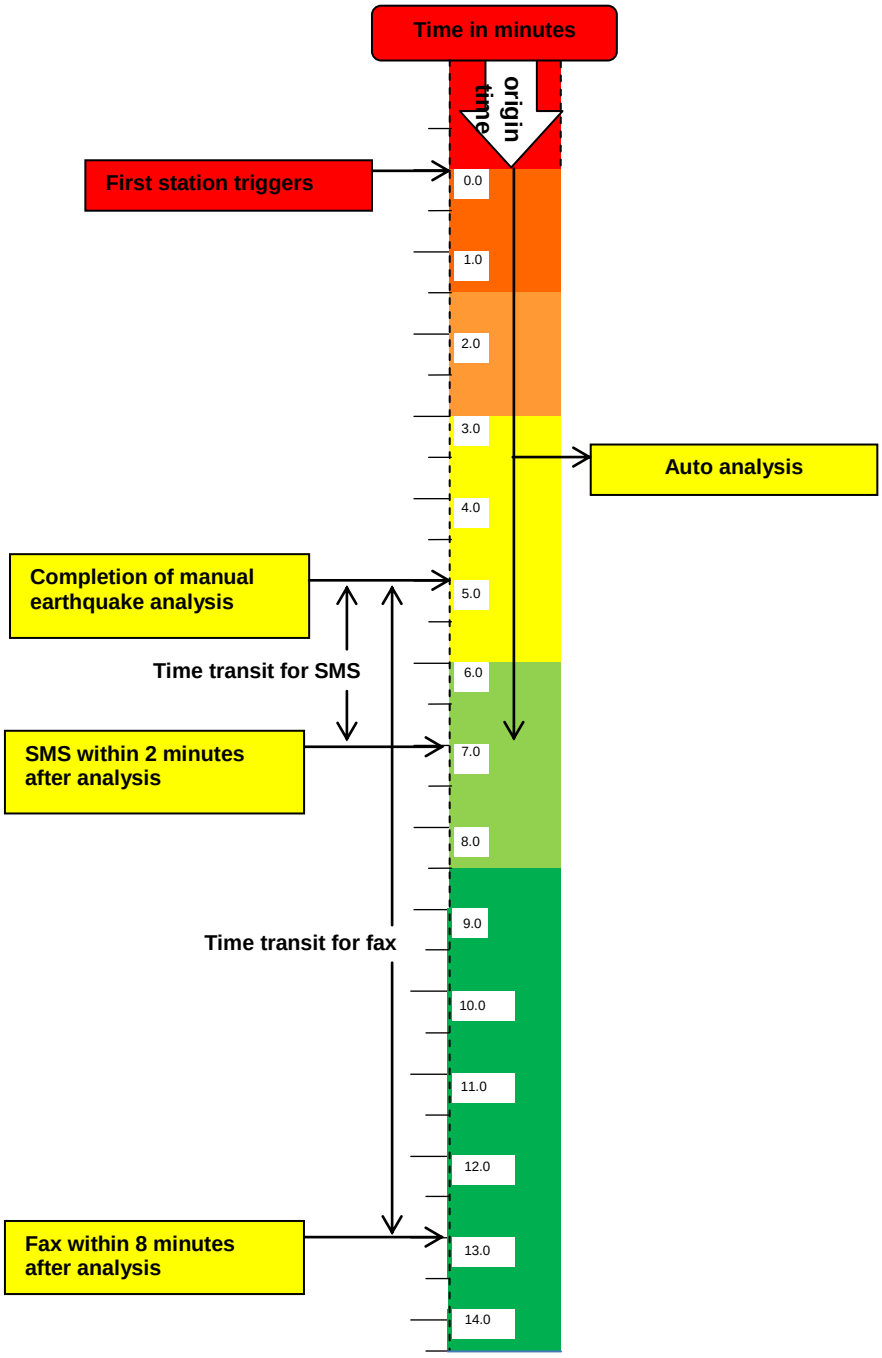


Figure 5: PMD bulletin series and cancellation for regional/local tsunami alerts

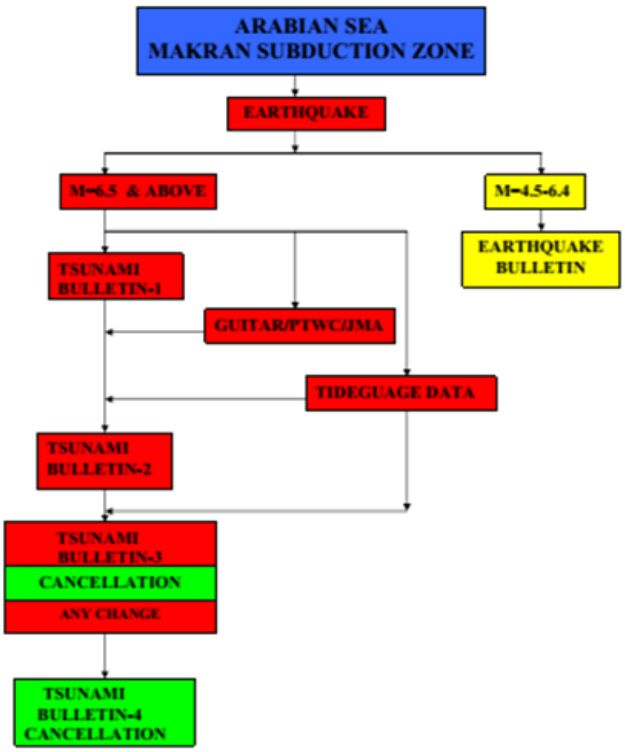


Figure 6: PMD bulletin series and cancellation for distant tsunami alerts

District Disaster Management Authorities (DDMAs)

Under national legislation, DDMAs have been established in every district, and are generally under the authority of the District Coordination Officer (DCO). When DCOs receive an alert from the PMD, they issue warnings to local communities on the basis of vulnerability assessments. Modes of communication include high-intensity sirens installed at mosques and special siren towers (though these are very limited in number). If there is a power failure, police, ambulance and fire brigade vehicles sound their sirens. The DDMAs maintain communications with agencies issuing early warnings via wireless channels. Depending upon their availability, telephone, fax and GSM mobile communications are routinely used to communicate with district sub-offices. All DCO offices in Sindh have facilities for video-conferencing, but this is dependent on the quality of the Internet connection. If an emergency is declared, the DDMA/DCO offices in that area establish emergency rooms that operate on a 24-hour basis to receive and pass on information locally and to provincial- and federal-level stakeholders. Authorities can also use local electronic media to release public messages.

The district-level administration (DCO office) has primary responsibility for communicating information to every community within its area, but it does not have specific time-bound SOPs on relaying information to communities in good time. The communication tools used by district offices are often unreliable, and DDMAs lack appropriate means of covering the last mile in difficult-to-access coastal areas – for example, boats and helicopters. In the case of an earthquake triggering a local tsunami, it may be less than half an hour before after the waves hit the coast. Cyclone monitoring generally allows a warning period of 2–3 days, and the most common way of alerting remote communities to potential threat in this case is to send district government officials, or more commonly armed forces or security agency personnel, to notify them in person. Officials travel by boat or by road to inform communities and to support evacuation plans.

National and Provincial Disaster Management Authorities (NDMA, PDMAs)

The NDMA and the PDMAs have internal SOPs to disseminate alerts and information to a further, limited number of recipients, including national- and provincial-level response organizations and media outlets. Early warnings are relayed (as appropriate) via email, phone, fax, GSM network, electronic media or press release. However, these SOPs are neither time-bound nor well coordinated with other agencies and organizations.

It must also be noted that because the media are often more interested in communicating news than disseminating early warnings, information is often sensationalized, which can result in panic on the ground.

3.2 EMERGENCY RESPONDERS

District government

The district government acts as an emergency responder despite having limited resources i.e. few vehicles or phones and fax machines to relay information. In remote areas, communities do not have access to phone and fax services and representatives must be sent by car or boat to convey early warnings and evacuation orders in person. Given the remoteness of many settlements and the lack of resources, the capacity of district governments in coastal areas is many cases inadequate. A district government can declare a situation an emergency and call for provincial and federal help if the response required is beyond its capabilities; however, this takes time, often at least 24 hours. This can be acceptable in the case of a cyclone warning received with 2–3 days' notice, but in the case of a local tsunami the lead time can be less than

30 minutes, and none of the six coastal district administrations is capable of responding adequately in such a short timeframe.

Police, armed forces and security agencies (Army, Navy, Coast Guards, PMSA)

Although Pakistan's armed forces and security agencies are equipped to deliver immediate relief and emergency response, they do not have SOPs for the dissemination of early warnings. However, they do have the means (satellite phones, HF/VHF radio, etc.) to ensure effective communication to those most at risk. In many creek areas, access is limited to boat only and no direct HF/VHF system is available. Again evacuation can be managed in the event of a cyclone warning, but for local tsunamis it is difficult to inform vulnerable communities in time and to manage evacuation without a direct mass notification system capable of reaching all of them.

Non-government organizations

Local NGOs have developed deep roots and an extensive network in the coastal areas of Sindh and Baluchistan. These NGOs have much of the required local knowledge and access to remote areas; however, such organizations are dependent on donor funding, which usually comes in post-disaster situations. If a disaster occurs, NGOs with a local presence – for example, Plan Pakistan,[13] HANDS,[14] the Indus Resource Centre (IRC)[15] and Association for Humanitarian Development (AHD),[16] among many others – work with international coordination groups such as UNOCHA and with local and provincial governments at least until the first phase of recovery. Previous disaster risk management (DRM) and contingency plans from 2008 to 2013, drawn up by the Provincial Disaster Management authority[17] identify the allocation of functions for different line departments and areas of coordination with NGOs and INGOs.[18]

The potential of these local organizations can be utilized by mapping the coastal communities at risk and devising SOPs for the dissemination of early warnings. Local NGOs have in the past been instrumental in assisting evacuations from hazard zones and in setting up relief camps and relief distributions in the coastal areas, for example during cyclones Gonu and Phet, and Cyclone Keila in 2011.

4 FIELD SURVEY OF COASTAL COMMUNITIES

Tsunamis of near origin, which account for most tsunami fatalities worldwide, pose the greatest hazard along the shores of the Arabian Sea. The nearby source of earthquakes for Sindh and Balochistan is the Makran Subduction Zone, an active seismic area extending under the sea. Earth scientists have suggested that the zone could produce an earthquake of magnitude 9, a worst-case scenario eclipsing the 1945 Makran earthquake, which was followed by a tsunami that claimed hundreds of lives. Coastal areas of Pakistan are also subject to tropical cyclones, as seen recently with cyclones Gonu and Phet.

Coastal communities are much more vulnerable today (to tsunamis, cyclones and also rising sea levels) than they were in 1945 due to factors such as high population density, rapid urbanization, lack of land use planning and the loss of natural barriers such as mangroves and sand dunes. In urban areas where multi-layer communication networks exist, it is assumed that emergency information can be delivered quickly, though how to manage evacuation from low-lying parts of Karachi has yet to be determined. Pakistan's coastal villages are vulnerable to marine hazards not solely because of poor communications, but also because of poverty and low levels of literacy.

For this study, 10 villages were selected to study the capacity of residents to receive and act on coastal hazard warnings, in particular for tsunamis. Eight of the villages are located in Sindh Province – in Thatta, Badin and Sujawal Districts, all in the Indus Delta – and the other two in Gwadar District of Balochistan Province. Further information on the surveyed villages is presented in Tables 2 and 3.

Figure 7: The boundaries of Thatta District, outlined in red

Thatta District

Thatta is an ancient city of the Indus delta situated about 100km from Karachi and connected via a national highway. The district is bounded to the north by Jamshoro District, to the east by Tando Muhammad Khan and Badin Districts, to the south by the Arabian Sea and the Great Rann of Kutch (a seasonal salt marsh) and to the west by Karachi District. It has a total area of 17,355 sq km and a population of around 1.2 million.

The following villages were visited as part of the field survey:

- Somar Dablo (Phirt Creek)
- Siddique Dablo (Tippun Creek)
- Dilli Sholani (Khobar Creek)
- Tayyab Jutt (Bhori Creek).

Left: On the second day of the visit, the team approaches Bhori Creek, Keti Bandar, where access is only possible by boat. Right: View of communities in Sindh Creek revealing lack basic infrastructure and construction pattern.

Hardly any of the villages surveyed have electricity from the national grid; instead, residents rely on solar panels provided by local NGOs to recharge their cellphones and occasionally to watch TV. No landline telephones are available and GSM networks are weak, patchy and in certain locations are only available occasionally. None of the villages can be reached by road and the only access is by boat. Boats are also used to bring in drinking water in tanks and provisions from nearby towns or cities, most often Keti Bandar. The villages also lack basic education and health facilities; the nearest health facilities are in Sakra, Gharo or Keti Bandar. The literacy rate is near zero.

Fishing is the main occupation in this area, while women make handicrafts to provide additional income. Residents lack local sources of clean drinking water and have few sanitation facilities. Fresh water in containers or tanks is purchased at a rate varying from RPKR 1,000 to RPKR 5,000 per tank in different villages, except in Tayyab Jutt village (Bhori Creek), where wells are dug to access ground sources of water.

Because of the inadequate sanitation and health facilities, most residents are exposed to diarrhoea, fever and flu. The daily sustenance for most is fish and vegetables that are purchased from Keti Bandar, as there are no local grocery shops in the village.


Left: There is no school in Tippun Creek, so instead children are engaged in household work or fishing. Right: Hand pump installed in Tayyab Jutt village, Bhori Creek: a freshwater ground source is available within the settlement.

For communications, most households rely on cellphones with weak and occasionally available networks in certain locations. Radio is available, but villagers tend not to listen to radio news broadcasts. They prefer to watch television, which is powered by solar panels or generators, but do not watch televised news on popular channels; rather, TV is used as a means of entertainment and to watch movies.

Disaster risk reduction (DRR) training for emergencies has been provided by WWF-Pakistan to residents of Dilli Sholani village (Khobar Creek). Villagers said that they were happy to receive this training but that a one-off activity was not enough for them to cope with any emergency situation in the area.

Sujawal District

Sujawal was formerly a *tehsil* (*taluka*)[19] of Thatta District, but in 2013 the Government of Sindh granted it the status of a district. It is located about 20km west of Thatta on the road from Badin to Karachi. Sujawal is largely an agricultural area with a few industries. Its residents are diverse in ethnicity and religion.

Two communities were selected in Sujawal District: Haji Yousuf Goth and Misri Jatt village in Rohro Creek. In the villages surveyed, there are no TV sets, but radios and 2–3 mobile phones are available for households. Early warning signals are usually received on radio sets (of which two were provided by WWF-Pakistan and two by the National Rural Support Programme (NRSP)).

Women collecting fresh water for drinking and household use. Rohro creek near Kharochhan city.

The primary occupation in the area is fishing. Residents in Yousuf Goth depend for drinking water on a large pond that fills from the Indus River during the June–July period and on the partially fresh water in the creek for the same period and the following 4–5 months. In the Kharo Chan area a few hand pumps were installed by WWF-Pakistan in 2014, giving villagers easy access to clean water.

Rohro Creek has a relatively high literacy rate of 30 percent of the population, but in Yousuf Goth only five people are able to read and write among 180 households. Training by WWF-Pakistan has resulted in a few families in Rohro Creek reducing the risk of flooding by elevating their homes.

Badin District

Figure 8: Boundaries of Badin coastal district outlined in red

Badin District lies on the lower Indus plain, which is formed by alluvial deposits from the Indus River. It is bounded to the north and west by Hyderabad and Thatta Districts, to the east by Mirpurkhas and Tharparkar Districts and to the south by the marshy Great Rann of Kutch, which also forms the international boundary with India.

The average land elevation of the district is about 50 metres above sea level, the lowest of the coastal communities surveyed. Its southern part lies near the delta of the river and its land surface is therefore lower than in the northern half, though the degree of slope in Badin is negligible. The eastern part of the district abuts the sand dunes of Tharparkar District.

Two communities were selected in Badin District: Peer Sheikh Prio and Goth Ramzan Sheikh. Peer Sheikh Prio is located about half a kilometre from the coast. It is 2km away from the main city (Badin city) and the road leading to the city is only paved halfway. The village has no health facility. Twenty of its 400 residents are literate and one has graduated from the University of Sindh in Jamshoro. Fishing remains the dominant livelihood activity. A large pond that fills up during the rainy season is used for drinking water.

Left: Access road to Peer Sheikh Prio village, Badin Disytrict. Right: View of market at last village of Taluka Jati, Goth Ramzan Sheikh, half a kilometre from the coast and adjacent to a Pakistan Rangers post

For early warning signalling, a coastguard post is located on the Darya Khan Bridge a couple of miles away. TV sets are available in two households, and are used to watch Sindhi news on local channels such as KTN. Electricity is not available via the national grid, but solar panels provided by various NGOs are used to recharge cell phone and torch batteries.

Goth Ramzan Sheikh and the surrounding area are lacking in basic facilities, including access to clean drinking water, communications and education. There is a relatively new government school in the village, which caters for 150 students and has a staff of four, though other children in the area have no school education. Residents get water from canals in the area, which is also used for drinking.

There is no early warning system in the area, but there is potential for one. Residents have TV sets run off a generator and have adequate access to cellular services. Additionally, they use mobile phones to keep up to date with current affairs.

Gwadar District

Gwadar District has a 600km long coastline is located immediately adjacent to the Persian Gulf shipping lanes. It has an area of 15,216 sq km and includes the dry tracts of the Kulanch and Dasht valleys. The district borders Kech and Awaran Districts to the north and northeast and Awaran and Lasbela Districts to the east; the Arabian Sea lies to the south and the Iranian territory of Sistan to the west.

Two communities were selected in Ormara *tehsil* in Gwadar, the villages of Sirki and Sonth. Both villages lie a long way from the coastal highway but can be accessed by four-wheel-drive vehicle in two hours. As they adjoin the seashore, both can also be reached by boat. Electricity is not available from the national grid, nor are there any telephone connections by wire. The GSM network is also very limited and only partially available in certain locations. Sirki has rudimentary communication services. Residents can sometimes access cellular services provided by Zong (China Mobile Pakistan) and also listen to radio news broadcasts. There are no other means of communication available to facilitate an EWS. Fishing remains the primary source of income. For clean drinking water, residents purchase 30-litre tanks of water at a price of RPKR 50 ($0.50) or use a well located a long distance from the village.

Left: Access to Sirki Village for at least one hour after 60 kilometers travelling on Coastal Highway, Tehsil Ormara, District Gwadar. Right: Access to Sonth village near Basool River, Ormara *tehsil*, Gwadar District.

Sonth has an abundant supply of water from the river and villagers also often dig wells, 4–6 feet deep, to access fresh drinking water. There is no electricity available in the village, and most households depend on solar panels for lighting and for charging mobile phone batteries. Zong is the only mobile network with a signal occasionally available in the region. Radio sets are present in almost every household and people listen to news broadcasts on BBC Urdu and Gwadar FM services.

Sirki village in Ormara *tehsil*, Gwadar District

4.1 DATA ANALYSIS

For the surveyed coastal communities, data were collected on their locations, their proximity to coastguard posts and possible routes of evacuation (Table 2) and their demographics and available communications systems (Table 3).

Table 2: Community structure: location, proximity to coastguard posts and possible routes of evacuation

		Thatta District, Keti Bandar				Sujawal District		Badin District		Ormara *tehsil*, Gwadar District	
Factor or parameter	**Communities**	**Phirt Creek**	**Tippun Creek**	**Khobar Creek**	**Bhori Creek**	**Rohro Creek**	**Haji Yousuf Goth**	**Peer Sheikh Prio**	**Goth Ramzan Sheikh**	**Sonth village**	**Sirki village**
Location	Distance from *tehsil* HQ (km)	5	5	10	7.5	25	25	25	50	>100	>100
	Distance from district HQ (km)	50	60	100	76	70	61	25	50	300	300
	Distance from coastal highway (km)	*N/A	*N/A	*N/A	*N/A	*N/A	*N/A	*N/A	*N/A	35	30
	Distance from coastline (m)	40	20	23	63	22	25	15	500	20	300
Elevation (m) above sea level		1.8	3.0	8.8	3.0	1.8	6	2.7	8	10	2.4
Pakistan Coast Guards (PCG) posts nearby		1 (Keti Bandar)	1 (Keti Bandar)	1 (Keti Bandar)	1 (Kharo Chan)	1 (Kharo Chan)	1 (Kharo Chan)	1 (Darya Khan Bridge)	1 (Darya Khan Bridge)	1 (Coastal Highway)	1 (Coastal Highway)
Direction of PCG post from community		E	E	NE	E	W	SW	N/A	N/A	N	N
Community distance from PCG post (km)		5	5	7.5	10	13.5	9.25	N/A	N/A	40	40
Line of sight from PCG post		No	No	No	No	No	No	No	No	Unclear (sandy)	Unclear (sandy)
Terrain issue from PCG post		Creek	Creek	Creek	Creek	Located far away	Located far away	Located far away	Creek	Sandy	Sandy
Possible evacuation route in the event of a tsunami	Exists	Only via boat	Only via boat	Only via boat	Only via boat	Road and via boat	Road and via boat	Road	Road and via boat	Road and via boat	Road and via boat
	Towards	PCG post	PCG post	PCG post	PCG post	Inland	Inland	Inland	Inland	Inland	Inland

* The Makran Coastal Highway has not yet been completed in Sindh.

Table 3: Community structure: demographics and available communications systems

			Thatta District, Keti Bandar				Sujawal District		Badin District		Ormara *tehsil*, Gwadar District	
Factor/parameter	**Communities**		**Phirt Creek**	**Tippun Creek**	**Khobar Creek**	**Bhori Creek**	**Rohro Creek**	**Haji Yousuf Goth**	**Peer Sheikh Prio**	**Goth Ramzan Sheikh**	**Sonth village**	**Sirki village**
Location	Latitude (E)		67° 24’ 29.1”	67° 23’ 85.2”	67° 26’ 19.7”	67° 28’ 71.6”	67° 41’ 80.4”	67° 39’ 13.2”	42° 87’ 06.5”	N/A	25° 18’5 7.899”	25° 23’ 08.999”
	Longitude (N)		24° 08’ 75.2”	24° 07’ 25.0”	24° 02’ 85.6”	24° 03’ 55.8”	24° 03’ 69.2”	24° 07’ 44.4”	26° 91’ 34.7”	N/A	64° 13’ 46.5”	64° 06’ 12.851”
Estimated population			250	300–325	400	2,100–2,800	50	600	400	8,000	600–700	600
Major population concentration			Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters
Number of households			35	40	50	300-400	350	180	60	800	60–70	60–70
Literacy rate (%)			0	0	0 (two persons are literate)	0	N/A	1% (five persons are literate)	N/A	N/A	1% (three persons)	3% (20 persons)
Maximum occupied area (sq km)			0.5	1	0.25	0.3	3	2	0.3	3	0.08	0.02
Community settlement pattern			Circular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	V-shaped	Irregular
Available telecom networks	Wired	Landline telephone	No	No	No	No	No	No	No	No	V-Phone*	No
		Internet	No	No	No	No	No	No	No	No	No	No
	Wire-less	GSM	Zong, Warid, Ufone*	Jazz, Telenor, Zong, Warid, Ufone*	Zong, Warid, Ufone, Jazz*	Zong, Warid, Ufone, Jazz*	Warid, Jazz	Jazz, Warid	Zong, Ufone, Telenor*	Zong, Ufone, Jazz, Telenor*	Zong*	Zong*

		Pakistan Coast Guards HF, VHF	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
		Wireless Internet	Yes	Yes	Yes	Yes	Yes	Yes	No	3G phone*	3G phone*	No
		Satellite phones	No	No	No	No	No	No	No	No	No	No
		Others	No	No	No	No	No	No	No	No	No	No
Electricity			No national grid but solar panels	Only solar panels	No, only torches	No, only torches	Only solar panels	Only solar panels	Only solar panels	Only solar panels	Only solar panels	Only solar panels
Radio reception			No	Yes	Yes	Yes	Yes (occasional)	Yes	Yes	Yes	Yes	Yes
Line of sight throughout the village			Clear up to mangroves	Clear	Clear up to mangroves	Clear	Almost clear, with vegetation and streams	Almost clear, with vegetation and streams	Clear above vegetation	Clear above vegetation	Clear	Sandy
Terrain			All flat, divided by water	All flat	All flat	All flat, divided by water	All flat	All flat	Almost flat	Almost flat	Almost flat	Sandy
Background noise level			Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural

* Partially and occasionally available.

5 REQUIREMENTS FOR AN EFFECTIVE EARLY WARNING SYSTEM

The ultimate goal of an effective early warning system is to provide the most effective coverage at the most affordable cost. Therefore it is critical to properly evaluate the characteristics and local needs of an area in order to design and implement an effective EWS. The information on communities in Tables 2 and 3 needs to be considered under the following parameters to formulate the basic blocks of a possible future warning system for coastal hazards.

Location and coverage

Information about the structure of a community and its access to communication channels is crucial in identifying the type(s) of method and system to be used, both for disseminating information and issuing early warnings. Information on village layout, population concentration and people's likely location, e.g. indoors or outdoors, gives an idea about the likelihood of effective penetration of an alert in a particular area.

Figure 9: Availability of telecommunications networks

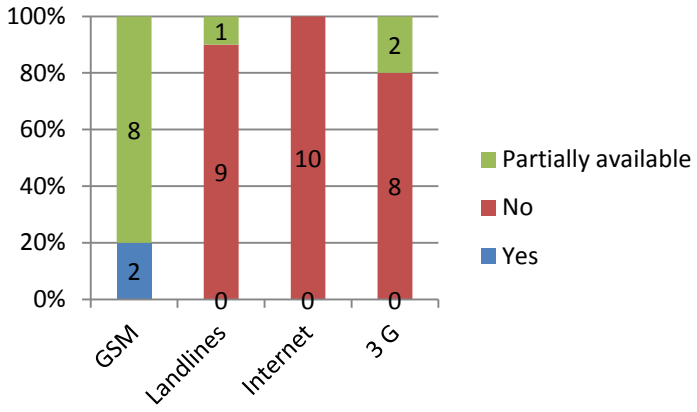


Figure 26 shows the availability of different types of phone network in the study areas. In most cases GSM coverage is partially available (80 percent), but GSM phones are available in all 10 villages, compared with one village where landlines are available (wireless VPhones from Pakistan Telecom) and two that have 3G services. Mobile networks are only partially accessible in most of the villages, with weak signals or no signal in many areas, both inhabited areas and more remote ones. Villagers have to reach out at certain locations for certain commercial GSM networks. Satellite phones could be used in all 10 surveyed villages; however, no community members use this mode of communication because of its very high cost.

Volume/audibility

For mass notification systems, information about the total occupied area is relevant in determining the volume (loudness) required for alerts and hence the number of sirens needed in a particular area and their effective positioning. For any type of siren, the perceived volume diminishes by 10 decibels (dB) for every doubling of distance between the siren and the point of measurement.

None of the sample communities occupies an area of more than 3 sq km, and so for each community a single mass notification unit (siren) with a sound intensity of 120–130 dB would be sufficiently loud to cover the whole area. This is similar, for example, to the Inmarsat system currently installed in Gwadar and Pasni cities.

Terrain and line of sight

In the case of a rapid-onset disaster like a tsunami, time can be saved and loss of life reduced by using a notification method that requires a minimum of human intervention. This can only be achieved if much of the hardware used for notification purposes is activated and operated remotely. Generally, radio wireless links with a good line of sight to such systems are used for such purposes. HF/VHF networks used by government agencies or emergency services are currently available nearing the vicinity of six of the 10 communities surveyed. A few systems which cannot be operated by radio links can be activated using satellite links.

Power sources

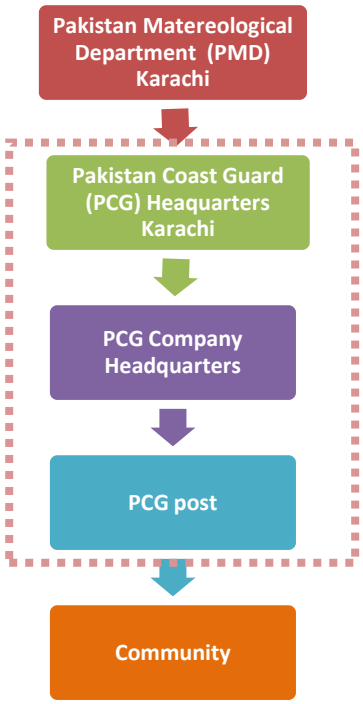
Almost all mass notification systems require electricity to function, though few rely on the main power system. Generally solar panels are used, though these are expensive and increase the overall cost of an EWS significantly. None of the sample communities have mains electricity, but all except Khobar and Bhori Creek have small solar panels, and these could be used as a power source.

Dissemination via the PCG network

Cyclone and tsunami warnings issued by the PMD are relayed first to the headquarters of the PCG in Karachi, which transmits them downstream through its internal networks to individual coastguard posts and hence to communities.

The cost and reliability of the 'last mile' relay of information from PCG posts to communities are generally dictated by three factors: the distance between the post and the community; the reliability of the means of dissemination used; and terrain issues.

Figure 10: Information flow of coastal hazards early warning from PMD to PCG posts and communities



Personal notification via PCG posts

Personal notification involves emergency personnel or trained volunteers going door-to-door or to groups of people to deliver warning messages in person. The field survey found that:

- Seven of the 10 communities are located at least 5km from the nearest PCG post.
- No other means of information dissemination exists in these communities.
- Evacuation routes are a long way from communities, so people have a long way to travel to reach safety.

The best use of this system in the current context is as an enhancement, used in combination with other notification systems. Its advantages and disadvantages are detailed in Table 4.

Table 4: Advantages and disadvantages of notification in person

Advantages	Disadvantages
High degree of credibility	Very time-consuming and slow
Provides all necessary information and instructions	Requires recruitment and training of large numbers of personnel
Very strategic notification	May require a large amount of logistics support (cars, boats, etc., accurate maps and route information, etc.)
Can access specific locations	Unable to reach a very wide area quickly
Cost-effective if using trained volunteers	Expensive if using paid personnel

Communities where dissemination is not possible via PCG posts

Sirki and Sonth villages lie a long way (40km) from the nearest coastguard posts, with serious terrain and line of sight issues. Hence information cannot be disseminated directly to these villages via PCG posts without the addition of repeater stations – however, these have a considerable cost and so this is not a feasible solution. In the current context there are two possible alternative solutions: mass notification systems activated via satellite and addressable notification systems i.e. satellite phones.

Mass notification systems activated via satellite

Mass notification systems activated via satellite, like the Inmarsat systems in Gwadar and Pasni, cover a wide area and can pass on information instantaneously. Such systems have a high degree of credibility and are very effective in terms of timeliness in an emergency. They have an average component cost comparable to other wireless mass notification systems, though the operational running cost of the satellite link must also be factored in.

Addressable notification systems – satellite phones

This type of solution includes satellite phones from companies such as Thuraya. There are some disadvantages of such systems in the current context: for example, they involve a continuous operational cost and raise issues of ownership, and they are generally intended for outdoor usage. However, satellite phone systems may be suitable for deployment in some communities despite their high cost.

6 CONCLUSION AND RECOMMENDATIONS

Tsunamis generated from a near source pose a deadly threat to communities in both developing and developed countries. The biggest challenge in relaying early warnings to vulnerable communities is the short reaction period, which can be as little as half an hour. This makes it a race against time in which every minute counts. However, cost considerations mean that is rarely feasible to deploy the best available technical solution; rather, a range of factors must be balanced up in order to arrive at the most cost-effective solution that will reach the greatest number of people.

For any tsunami generated from the Makran Subduction Zone, the PMD is the only organization in Pakistan authorized to issue warnings. The agency uses reliable data from national and global seismographic monitoring networks and, to issue warnings, it uses multiple channels of communication, including SMS messaging and fax (both automated and manual), satellite phones, website updates and email. However, the communities most at risk are largely unable to access this vital information, as is evident from the survey of the 10 coastal communities.

These communities (like many others) lie a long way from *tehsil* and district headquarters, which are the most devolved government administrative units to receive early warning communications. Distances range from 5km to 300km (Table 2), making it very difficult to send messengers to notify even the closest communities of danger in person, and impossible for those lying further away.

Pakistan Coast Guards posts are generally located closer to communities, on average 16km away, compared with 35.25km for *tehsil* and 82.2km for district HQ. These posts are also equipped with the fastest means of communication, e.g. HF/VHF radio networks, but at present these are restricted to security uses only. To enable these networks to be used for early warning and emergencies, new agreements, protocols and SOPs would need to be established between the organizations concerned.

For other means of communication, such as phone, TV and fax, neither electricity nor landlines are available in any of the villages studied (Table 3). GSM networks are available in some locations but reception is patchy and limited, meaning that this is not yet a sufficiently reliable means of early warning dissemination. Most households have access to radio, but there are two issues to be tackled here, at different levels: lines of communication between the PMD and radio broadcasters to be improved, and the batteries needed to power radio sets are not easily available locally.

The populations of the communities studied vary from 50 individuals to 8,000 concentrated, on average, in an area of less than 2 sq km. Four of the 10 settlements are located on creeks and are only accessible by boat; three of these have populations of fewer than 1,000 while the biggest has 2,800. Until recently, the only way of communicating early warnings of cyclones to these communities was in person i.e. armed forces or security agency personnel would travel to the villages by boat or by road to warn residents to evacuate. However, this took hours and sometime days; in the event of a local tsunami a much quicker reaction would be required.

The SOPs of the PMD alone are not sufficient to prepare for the threat of a local tsunami. There is an urgent need to develop a well coordinated and time-based set of SOPs for all stakeholders involved in the warning and evacuation chain, and a need to enhance technical capacities to quickly relay information over the last mile. This should not be the last but the first step towards mitigation and preparedness, as there are still many other issues to tackle: for example, effective land use management and expanding databases on hazards and the vulnerabilities of the areas at risk. Incorporating the high-tech communication networks available to the armed forces and security agencies into the early warning chain would be one way to reduce the strain on the country's limited resources. Above all, the most urgent and important course of action in

the immediate short term is to educate communities to observe natural warning signs and to train them for self-evacuation and emergency response.

RECOMMENDATIONS

The following recommendations are made to help strengthen the early warning dissemination system for coastal hazards in Pakistan.

Technical solutions

- Taking into account its capacity for a quick response and its reliability, the best solution for Phirt Creek, Tippun Creek, Khobar Creek, Bhori Creek, Misri Jatt village, Haji Yousuf Goth and Goth Ramzan Sheikh would be a wireless-operated mass notification system.
- If budgetary constraints preclude this, the next best solution for these communities would be to use local radio channels to broadcast warnings, backed up by notification in person, with capacity-building measures undertaken in target communities, including training and media.
- For the villages of Sirki and Sonth, the best solution would be a satellite-activated mass notification system; as a second option, satellite phones are recommended for mass notification.

Delineation of responsibilities

There is a need to map the presence on the ground and resources of all relevant agencies (including security forces) and to develop SOPs that define their roles and responsibilities in an emergency, based on their existing resources for effective dissemination of information.

Self-response training for communities

Although communities are aware of coastal hazards, they rarely know how to address an emergency situation when it arises. It is important that communities are trained on:

- detection of early warning via natural signs, such as abnormal behaviour of animals, etc.;
- basic emergency response, especially how and where to evacuate to;
- understanding bulletins issued by the PMD and the DDMAs;
- different categories of threat and how they should respond to them.

Communication of early warning in local languages

In addition to the existing format, the PMD should ensure that its bulletins are available and disseminated in local languages, particularly Sindh and Balochi.

Training for media outlets

In the past, media outlets have had a tendency to sensationalize news. Broadcasters should be trained on how to communicate early warnings so that panic can be avoided. It would also be in the interests of the PMD and the NDMA to have designated representatives to coordinate with the media in the event of an emergency.

Land use management

People tend to settle on remote islands in the coastal belt and, due to a lack of development in these areas, means of communication are limited, making communities more vulnerable to

coastal hazards. It is recommended that the authorities establish a land use management system that disseminates knowledge on land use along the coastal belt and discourages further settlement in remote locations that cannot be easily accessed, especially in emergencies.

It is important to note that development usually takes place around a central point and infrastructure is installed gradually. Public authorities and private providers cannot invest in infrastructure everywhere, which means that remote settlements have limited access to utilities. The government cannot be blamed for this, and should not be held responsible for providing infrastructure to the most isolated communities.

Research

There is a need for more research to investigate which areas are vulnerable and to assess the potential extent of damage, based on extrapolations of historically available data. For example, it is important to establish how much more vulnerable Karachi might be to a tsunami similar in size to the 1945 event, considering the growth since then in its population and infrastructure.

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NOTES

1 Hoffmann et al. (2013).

2 http://www.ndma.gov.pk

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13 https://plan-international.org/pakistan

14 http://www.hands.org.pk/2012/

15 http://www.irc-pakistan.com/

16 http://www.ahdpak.org/

17 www.pdma.gos.pk and www.pdma.gob.pk

18 IRF Vulnerability Assessment Report for three districts of Sindh, March 2015.

19 A *tehsil* is the second lowest tier of local government in Pakistan, a sub-division of a district roughly equivalent to a town council. In Sindh Province, the term *taluka* is more commonly used.

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