

An Inception Report
on
“Tsunami Early Warning System and Standard Operating Procedure
of Pakistan Meteorological Department”



by
Najeeb Ahmed Amir, Deputy Director
National Seismic Monitoring and tsunami Early Warning Center
Islamabad

Abstract

National seismic monitoring center of Pakistan Meteorological Department (PMD) consists of 20 Broadband seismic stations and 15 short period seismic stations equipped with Guralp, UK and Chinese seismic technology. Main purpose of the network is to monitor the earthquake activities in Pakistan and further detect any tsunamigenic earthquake along Makran Subduction Zone due to available history of 1945 tsunami. Further based on this monitoring activity Pakistan Meteorological Department issues both earthquake press-release to concerned disaster agencies like NDMA and further it has developed a Standard Operating procedure for implementation of necessary action plan to cope in case of any devastating earthquake. This is the main task of PMD which is doing efficiently at National level.

Introduction

A Network of land-based seismic stations for earthquake detection and estimation of focal parameters is a prime requirement of the warning centre. Tsunami Early Warning Centre is receiving real-time seismic data from local as well as international seismic networks through internet and has been detecting all earthquake events occurring in the Indian Ocean. Necessary software (Seiscomp3) has been installed for real-time data reception, archiving, processing and auto-location of earthquakes as well as for alert generation.

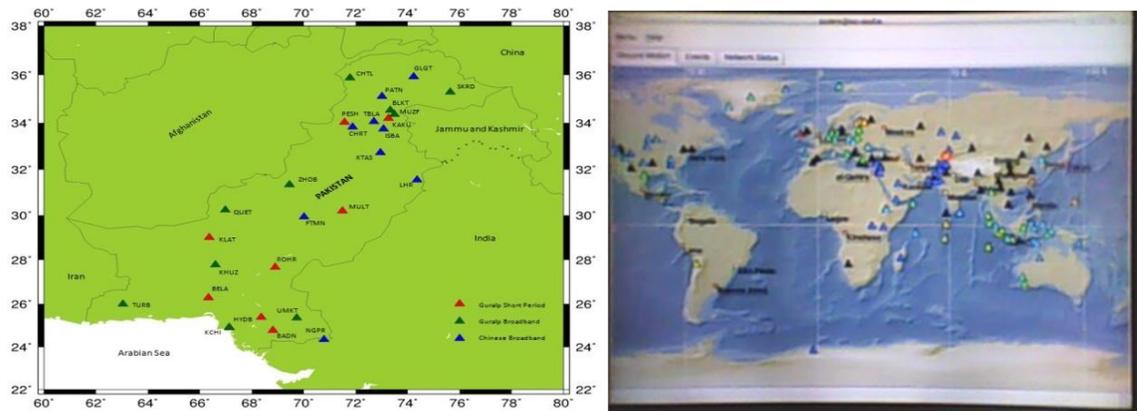


Figure 1: BB Seismic Network of Pakistan and Global Coverage

Earthquake Analysis



Figure 2: Earthquake Data Analysis View

These are the key components of the tsunami early warning system of PMD to issue necessary press-release and follow the SOP in case of any damaging earthquake in and around Pakistan.

Monitoring of Sea Level

In order to confirm whether the earthquake has actually triggered a tsunami, it is essential to measure the change in water level with high accuracy. A network of tidal gauges along the coast helps to monitor progress of tsunami. Pakistan Navy has setup a network of tidal gauges at Ormara, Gwadar and Keti-bandar where as at Karachi it is under the control of Pakistan Navy.

Near-real time sea level data is being received from national and international centers through IOC sea level monitoring website.

Tsunami Modeling:

For operational quantitative tsunami forecast, there needs to be a method to quickly estimate the travel times and run up heights. Tsunami simulation software “Guitar” is available for this purpose. Software is linked with Earthquake Analysis Software to calculate estimated Tsunami Arrival Times and Wave Heights which are incorporated in the tsunami warning products.

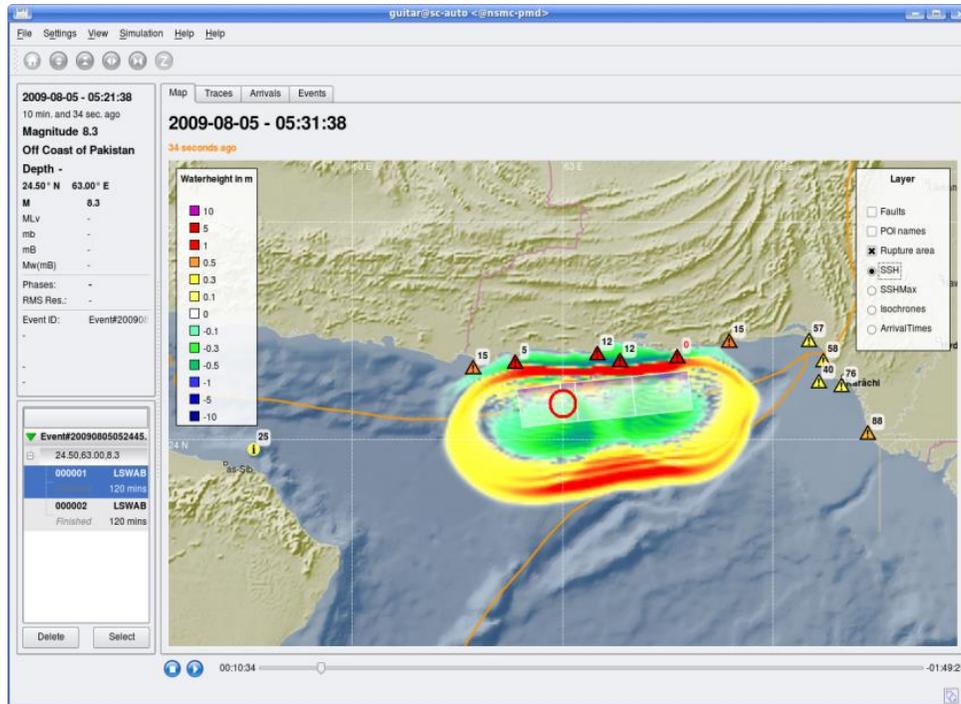


Figure 3: Guitar Software tsunami simulation for an earthquake in Arabian Sea

Tsunami Early Warning Centre Setup

A dedicated 24 x 7 operating Tsunami Warning Centre comprising necessary computational, communication and technical support infrastructure as well as a robust application software that facilitates data reception, display, analysis, modeling, and decision support system for generation of tsunami advisories following a standard operating procedure has been established. The warning centre continuously monitors seismic activity in the two tsunamigenic source regions and sea level through the network of national and international seismic stations as well as tide gauges. The monitoring of water level enables confirmation or cancellation of a tsunami. Tsunami bulletins are generated based on pre-set decision support rules and disseminated to the concerned authorities for action, following a Standard Operating Procedure (SOP).

STANDARD OPERATING PROCEDURE (SOP) for Tsunami Early Warning

- i. Is the procedural guidance and actions to be taken to notify the Tsunami information, in case an earthquake occurs in the Arabian Sea (Makran Subduction Zone) or Indian Ocean (Sumatra & Surroundings).
- ii. Is a set of written instructions describing routine or repetitive activities to be followed by TEWC staff during a Tsunami event which may occur in any of the above oceanic area. These activities include data processing, evaluation of tsunami, issuance of bulletins using multi-channelled communication; estimation of the arrival times and wave heights using software; monitoring sea level data to confirm or cancel the Tsunami warning; collection of information from Regional Tsunami Service Providers (RTSPs) through

GTS/website/Media channels and incorporate this information in the bulletins issued by the centre.

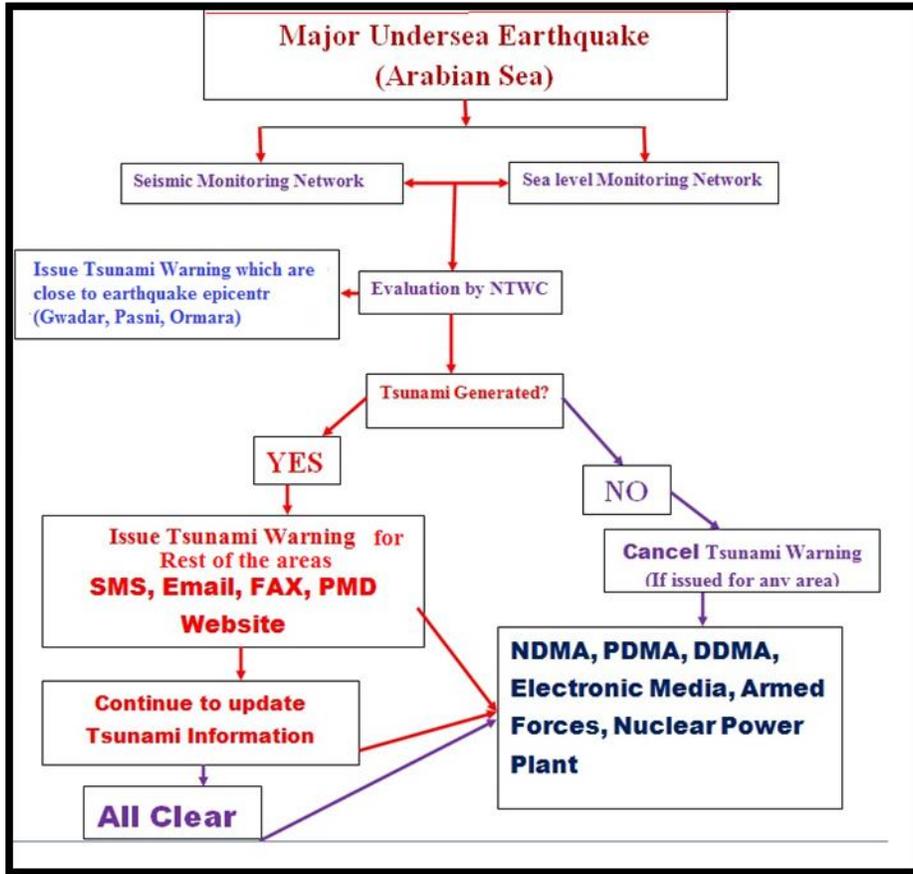


Figure 4: Schematic Diagram for SOP of PMD

SOP is based on the following basic principals

The criteria for generation of different types of advisories (warning) for a particular region of the coast are to be based on the available warning time (i.e. time taken by the tsunami wave to reach the particular coast). The warning criteria are based on the premise that coastal areas falling close to a tsunamigenic earthquake source (Gwadar, Pasni and Ormara) need to be warned based solely on earthquake information, since enough time will not be available for confirmation of water levels from tide gauges. Those coastal areas falling far away from a tsunamigenic earthquake source could be put under a standby status and upgraded to a warning only upon confirmation of water-level data. However following are the main principles:

- Monitor the online input data from individual sensors,

- Generate automatic advisories/warnings based on preset decision rules for one or many of the input parameters.
- Carry out criteria-based analysis for one or many of the above mentioned input parameters to generate warnings.

BULLETIN ISSUANCE CRITERIA

The following three parameters are used to evaluate the tsunamigenic potential of an earthquake.

- **LOCATION:** - Whether the earthquake is located under or very near the sea.
- **DEPTH:** - Whether the earthquake is located close enough to the surface to have caused a significant displacement of that surface.
- **MAGNITUDE:** - Various magnitude ranges and their combination with other parameters for Makran Subduction Zone are shown in the following table.

LOCATION	MAGNITUDE	TSUNAMI POTENTIAL	ACTION
Arabian Sea	< 6.5	No Tsunami Threat	Earthquake Parameters with “No Tsunami Threat”
	6.5 to 7.0	A small possibility of local destructive Tsunami	Tsunami Bulletins
	7.1to 7.5	Local destructive Tsunami	Tsunami Bulletins
	7.6 to 7.9	Regional/Wide-spread destructive Tsunami	Tsunami Bulletins
	8.0 & above	Wide-spread destructive Tsunami	Tsunami Bulletins

TYPE OF MAGNITUDE

The magnitude used by NSM & TEWC is the moment magnitude, Mw, because for large earthquakes, it is more accurate and reliable than other magnitudes.

LOCAL TSUNAMI

A local Tsunami is the one with destructive or life threatening effects usually limited to within the radius of 100 km of the epicenter.

REGIONAL TSUNAMI

A Regional Tsunami is one with destructive or life threatening effects usually limited to within the radius of 1000 km of the epicenter.

OCEAN-WIDE TSUNAMI

By Ocean-Wide Tsunami is meant a Tsunami with destructive or life threatening effects that can extend across the entire ocean basin.

BULLETIN CONTENTS

Bulletins are divided into four sections. A “Header” gives the Bulletin number and time of issuance. The number starts from 1 and is incremented to maximum 4 for a tsunami event in Arabian Sea and 2 to 4 for Sumatra and surroundings. Below header, it is indicated that who is issuing agency, e.g. PMD, followed by the earthquake parameters including origin time, location co-ordinates, location name, depth and magnitude. The next section is the evaluation regarding potential, destructive effects of tsunami and advice for evacuation. The incremental Bulletins 2 and 3 have the sections regarding estimated arrival times/wave heights and tide gauge data at key locations. In case of no tsunami generation, Bulletin-3 will be treated as cancellation for Makran and Sumatra Subduction Zones. In case of confirmation of tsunami generation Bulletin-4 will serve as cancellation. Sample Bulletins are provided, separately for Makran Subduction Zone and Sumatra. Arrival times and wave heights provided by GUITAR simulation software are also placed as sample.

BULLETIN DISSEMINATION

The following circuits and methods are used to disseminate Tsunami Bulletins:

- i. Mobile phone based SMS.
- ii. Automated fax- 2 Channel.
- iii. Manual fax- 1 Channel.
- iv. Website updating www.pakmet.com.pk/seismic and e-mail

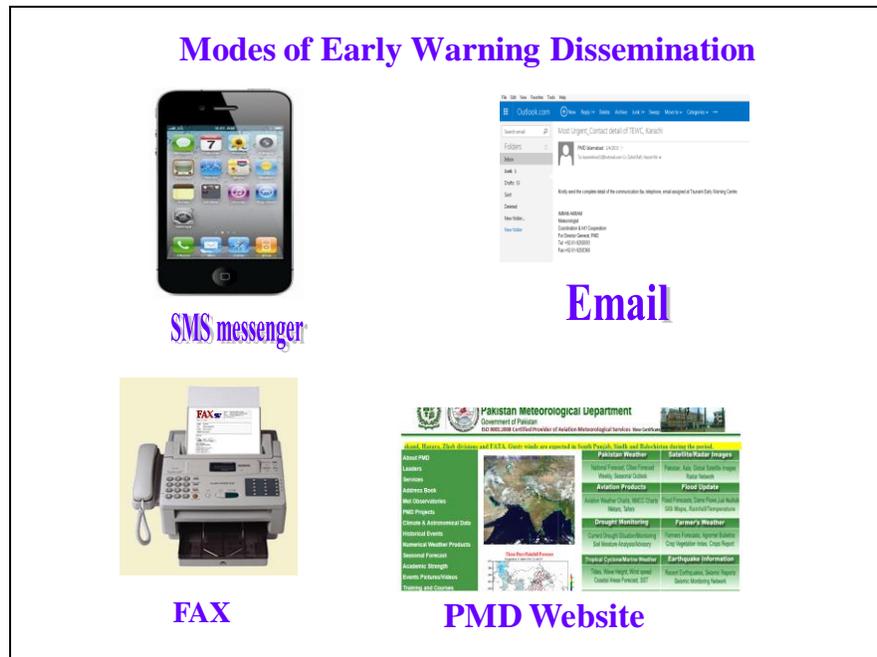


Figure 5: Modes of Tsunami Warning Dissemination

RECEPTION OF THE TSUNAMI BULLETINS FROM INTERNATIONAL ORGANIZATIONS (PTWC)

The centre has a GTS terminal, through which Tsunami information bulletins are received from RTSPs of Australia, Indonesia and India. The information contained in these bulletins is incorporated in the products of the centre.

GTS Link for IOTWS/RTSPs-UNESCO

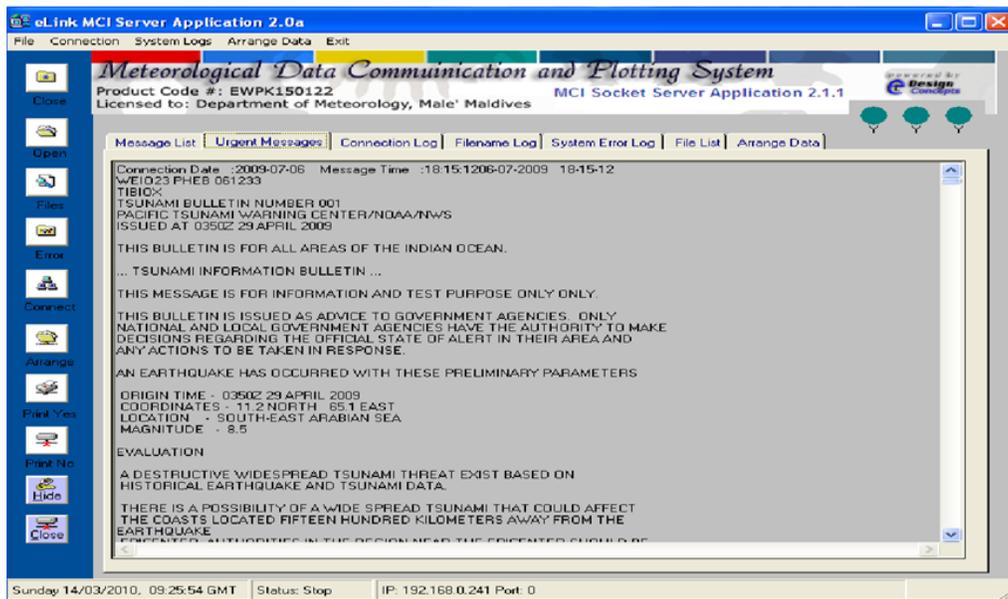


Figure 6: GTS Link for IOTWS/RTSPs-UNESCO

TESTS AND EXERCISES

NSMC, Karachi conducts regular tests to check the operational status of data acquisition system, communication system and dissemination system. Exercises are also carried out repeatedly to test the SOP. For this purpose dummy messages are sent with the header of "TEST", to ensure that the message is not misunderstood. The centre regularly participates in the IOWave exercises as and when scheduled by IOTWMS/UNESCO.

Sop for Issuance of "Tsunami Bulletins" In Arabian Sea (Makran Subduction Zone)

- i. For earthquakes having magnitude between 4.5 to 6.4 only earthquake parameters with no tsunami threat will be sent to RESPONSE AUTHORITIES and MEDIA through SMS and FAX.
- ii. Maximum four Bulletins will be issued for earthquakes having magnitude 6.5 or above to RESPONSE AUTHORITIES and MEDIA.

BULLETIN-1:-

This bulletin will contain;

- i. Earthquake Parameters.
- ii. Tsunami evaluation based on historical earthquake and tsunami data.
- iii. Advice to evacuate or put into standby status.

This bulletin will be issued according to time line of Bulletin-1

BULLETIN-2:-

This bulletin will contain;

- i. Revised Earthquake Parameters (if so).
- ii. Estimated arrival times and wave heights at various locations along Pakistan Coast based on GUITAR/RTSPs.
- iii. Tide gauge data if generation of tsunami has been confirmed.
- iv. Advice for evacuation

This bulletin will be issued soon after the dissemination process of Bulletin-1 is completed.

In case the Tsunami generation is confirmed, the first sentence of Evaluation will be deleted.

BULLETIN-3:-

This bulletin will contain;

- i. Revised earthquake parameters (if so).
- ii. Tide gauge data of Pakistan Coast to confirm the generation of tsunami
- iii. Any change if tsunami has been confirmed in Bulletin.
- iv. This bulletin will serve as cancellation in case a sufficient time has lapsed after the estimated arrival time but no significant change is observed in sea level. In such case it will be the last bulletin.

This bulletin will be issued when ever tide gauge data confirms the tsunami generation (CONFIRMATION).

BULLETIN-4:- (Cancellation)

- i. This bulletin will contain earthquake parameters and tsunami evaluation regarding cancellation.
- ii. This will be the last bulletin and will serve as cancellation.

TSUNAMI WARNING TIME LINE FOR SOP

TIME LINE FOR EARTHQUAKE PROCESSING AND DISSEMINATION OF TSUNAMI BULLETIN (FOR MAKHRAN SUBDUCTION ZONE)

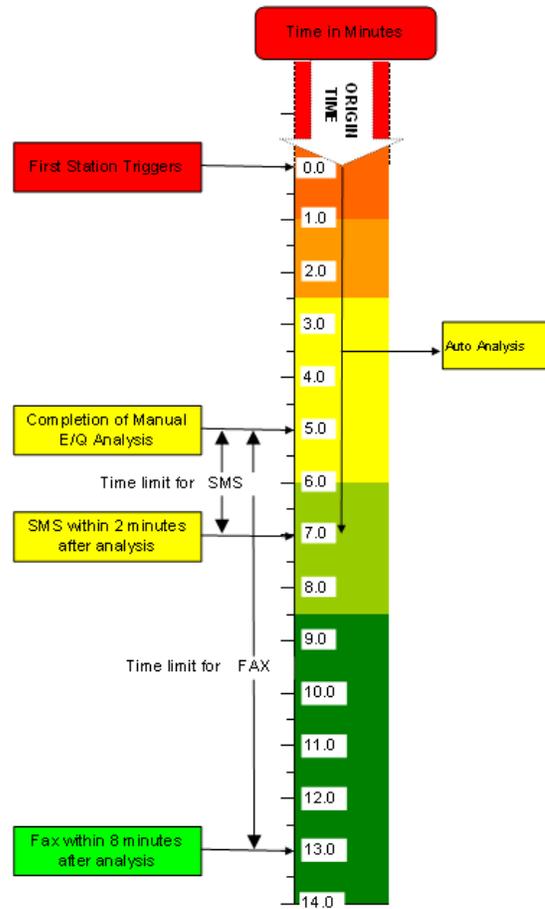


Figure 7:Time-Line for Tsunami Early Warning

MESSAGE TEMPLATES

DESCRIPTION OF MESSAGE (SMS)
E/Q M 8.7 occurred off coast of Pakistan on 08-09-2016 at 11:00PST. Destructive tsunami may generate. Immediate evacuation is advised along coastal areas of Balochistan and rest is advised to standby for evacuation.PMD.(Issued at 1105 PST)
E/Q M 9.0 (revised) occurred off coast of Pakistan on 08-09-2016 at 11:00PST. Destructive tsunami may generate. Immediate evacuation is advised along coastal areas of Balochistan and rest is advised to standby for evacuation. PMD.(Issued at 1110PST)

E/Q M 9.0 (revised) occurred off coast of Pakistan on 08-09-2016 at 11:00PST. Destructive tsunami generation has been confirmed. Immediate evacuation is advised along all coastal areas of Pakistan. PMD.(Issued at 1130 PST)

E/Q M 9.0 (revised) occurred off coast of Pakistan on 08-09-2016 at 11:00PST. Tsunami Threat has passed. All Clear will be decided by local authorities. PMD.(Issued at 1600 PST)

**(SEVERE TSUNAMI THREAT)
EXAMPLE BULLETINS**

TSUNAMI BULLETIN-01

Issued at 11:05:00 PST

National Tsunami Warning Centre (NTWC), Karachi of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Origin time 08-09-2016 at 11:00:00 PST

Magnitude: 8.7

Depth: 10 Km

Latitude: 24.80° N

Longitude: 62.20 ° E

Location: Off Coast of Pakistan

EVALUATION:

. Based on the historical data, earthquakes of this size may cause wide-spread inland damages and Destructive Tsunami generation in the Arabian Sea and along coastline of Pakistan. However, it is not known that a tsunami has been generated. This bulletin is based only on the earthquake evaluation. Monitoring of Sea Level Gauges is under way to determine if a tsunami has been triggered. **People in coastal areas of Balochistan especially Jiwani, Gwadar, Pasni, Ormara and neighborhood are STRONGLY ADVISED TO EVACUATE IMMEDIATELY** to higher grounds or go far inland. **People in coastal areas of Sindh are advised to standby for evacuation.** Boats and Ships at sea are advised to stay in the deeper parts of the sea until the threat is over. If there is sufficient time, boats and ships in harbors and bays are advised to go to the deeper parts of the sea until the threat is over.

UPDATES

Additional bulletins will be issued by NTWC, Karachi for this event as more information becomes available.

Sd/=

Duty Seismologist

(SEVERE TSUNAMI THREAT)

TSUNAMI BULLETIN-02

Issued at 11:10:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Origin time: 08-09-2016 at 11:00:00 PST

Magnitude: 9.0 (Revised)

Depth: 10 Km

Latitude: 24.80° N

Longitude: 62.20° E

Location: Off Coast of Pakistan

EVALUATION: It has not been confirmed whether Tsunami has been generated or not. Based on the historical data, earthquakes of this size may cause wide-spread inland damages and Destructive Tsunami generation in the Arabian Sea and along coastline of Pakistan. However, it is not known that a tsunami has been generated. This bulletin is based only on the earthquake evaluation. Monitoring of Sea Level Gauges is under way to determine if a tsunami has been triggered. **People in coastal areas of Balochistan especially Jiwani, Gwadar, Pasni, Ormara and neighborhood are STRONGLY ADVISED TO EVACUATE IMMEDIATELY** to higher grounds or go far inland. **People in coastal areas of Sindh are advised to standby for evacuation.** Boats and ships at sea are advised to stay in the deeper parts of the sea until the threat is over. If there is sufficient time, boats and ships in harbors and bays are advised to go to the deeper parts of the sea until the threat is over.

SIMULATION RESULTS:

According to pre-run scenarios estimated initial tsunami wave arrival times and amplitude of the maximum tsunami wave, at the various locations are given below. However, actual wave arrival times and maximum amplitude may differ from those below, and the initial wave may not be the largest. A tsunami is a series of waves and the time between successive waves can be five minutes to one hour.

CITY NAME	ARRIVAL TIME (PST)	WAVES HEIGHT (meters)
JIWANI	1115PST 08 Sep 2016	12.5 m
GAWADAR	1115 PST 08 Sep 2016	12.0 m
PASNI	1115PST 08 Sep 2016	13.6 m
ORMARA	1115PST 08 Sep 2016	12.8 m
BAGAR	1115PST 08 Sep 2016	12.0 m
KUNDMALIR	1130PST 08 Sep 2016	07.3 m
ASTOL	1115PST 08 Sep 2016	08.2 m
WINDER	1145PST 08 Sep 2016	11.0 m
GADANI	1147PST 08 Sep 2016	05.2 m
KARACHI	1155PST 08 Sep 2016	04.1 m
KETIBANDAR	1205PST 08 Sep 2016	04.1 m
THATTA	1209PST 08 Sep 2016	03.7 m
BADIN	1230PST 08Sep 2016	03.5 m

UPDATES

Additional bulletins will be issued by NTWC, Karachi for this event as more information becomes available.

Sd/=

Duty Seismologist

(Confirmed Tsunami Threat)

TSUNAMI BULLETIN-03

Issued at 11:30:00 PST

National Tsunami Warning Centre (NTWC) of Pakistan Meteorological Department has recorded an Earthquake with the following preliminary seismological parameters:

Origin time: 08-09-2016 at 11:00:00 PST

Magnitude: 9.0 (Revised)

Depth: 10 Km

Latitude: 24.80° N

Longitude: 62.20° E

Location: Off Coast of Pakistan

Pak.Met.Dept

OBSERVATION OF TSUNAMI ACTIVITY:

Sea level observations confirmed that a **destructive tsunami has been generated**. All the People at coastal areas of Pakistan are advised to **evacuate immediately to higher grounds or go far inland**.

Arrival times and wave heights, as observed at Tidegauges locations, are given below;

Gwadar	25.6N 57.8E	1125 PST 08 Sep 2016	13.5m
Ormara	25.3N 60.6E	1127 PST 08 Sep 2016	12.8m

UPDATES

Additional bulletins will be issued by NTWC, Karachi for this event as more information becomes available

Sd/=

Duty Seismologist

CONCLUSIONS

As Pakistan lie at marginal collision zone of Indian and Eurasian plates. Deformation due to this collision has produced many damaging earthquake across the country. These earthquakes had colossal devastating impact for the region. This is the main task of PMD which is doing efficiently at National level. Therefore National seismic monitoring center of Pakistan Meteorological Department (PMD) has great importance in monitoring necessary earthquake activities in Pakistan and further SOP of PMD is very important for concerned disaster agencies like NDMA for implementation of necessary action plan to cope in case of any devastating earthquake.

Tsunami Alert Response Authorities List

S.NO.	ORGANIZATION	FOCAL PERSON	MOBILE NO.	OFFICE NO.	FAX NO.	EMAIL/ADDRESS
01	NDMA	L.T.COL.RA ZA IQBAL	0301-5565737	051-9105035	051-9205086	dirresponse@ndma.gov.com
02	PDMA(Balochistan)	Zahid Saleem	0300-8384489	0812-881168	0812-880189	NIL
03	Deputy Commissioner (Lasbella)	CAPT.ALI IIAZ	0345-4500296	0853-610231	0853-610252	alithecavalier@gmail.com
04	Deputy Commissioner (Gwadar)	NIL	NIL	NIL	0864-211362	NIL
05	PDMA(Sindh)	AKHLAQ QURESHI	0300-8281311		021-99251463	8281311@gmail.com
06	AHQ Peshawar	Director Met	03239403109			
07	Deputy Commissioner (Badin)	SYED.ATTA ULLAH SHAH	0333-2851860		0297861996	majeedhaber@gmail.com
08	Deputy Commissioner (Thatta)	NIL	NIL	NIL	0298-920058 0298-220069	
09	KPT(Operation)	UMAIR	0333-2405650	021-99214555	021-99214555	umkpt@yahoo.com
10	KPT(Hydrographer)				021-99214555	
11	PAK NAVY	L.T.CDR.TA NVEER SHAMS HQ NAVAR EA-IX	0321-2435236	NIL	021-99201623	hydrotk@paknavy.gov.pk hydrtk@gmail.com
12	KANUPP	CONTROL ROOM MUSHTAQ.	0300-8216933	NIL	021-99204490 021-99202240	knpc@knpc.gov.pk
13	OPs Room ORO NHQ	NHQ		NIL	051-9261551	dno@paknavy.gov.pk
14	OpsRoomHQ	COMLOG	0336-2216416	NIL	021-99204910	NIL
15	Ops Room HQ	COMCOAST	0335-1374803	NIL	021-99201783	com.coast@paknavy.gov.pk
16	Ops Room HQ	COMKAR	0313-8671697	NIL	021-99201795	Oro767@gmail.com
17	OPERATION Room HQ	COM PAK		NIL	021-35867737	Shipping912@yahoo.com
18	J.D.E. WELFARE ORG (NGO)		0334-3443313	021-32033345		
19	Commission Karachi	ANIS AHMED USMANI	0345-2834688	021-99204451	021-99204729	NIL
20	Lt Ahmed	J.M.I.C.C(M ANORA)	0342-2977709 0335-8107739		021-99232196	jmio@paknavy.gov.pk
21	PDMA(SINDH(2)	SHAYYAN DY DIRECT OR	0300-9371186			m.shayyanshah@hotmail.com
22	PAF Base Masroor	DFO	03239432117			