

PARTICIPANTS

Members

Dr. Abdolmajid Naderi Beni (Acting Chair, Iran)
Mr. Patanjali Kumar Chodavarapu (India)
Dr. Issa El-Hussain (Oman)
Mr. Ameer Hyder (Pakistan)
Mr. Khalifa Alebri (UAE)

Invited Expert

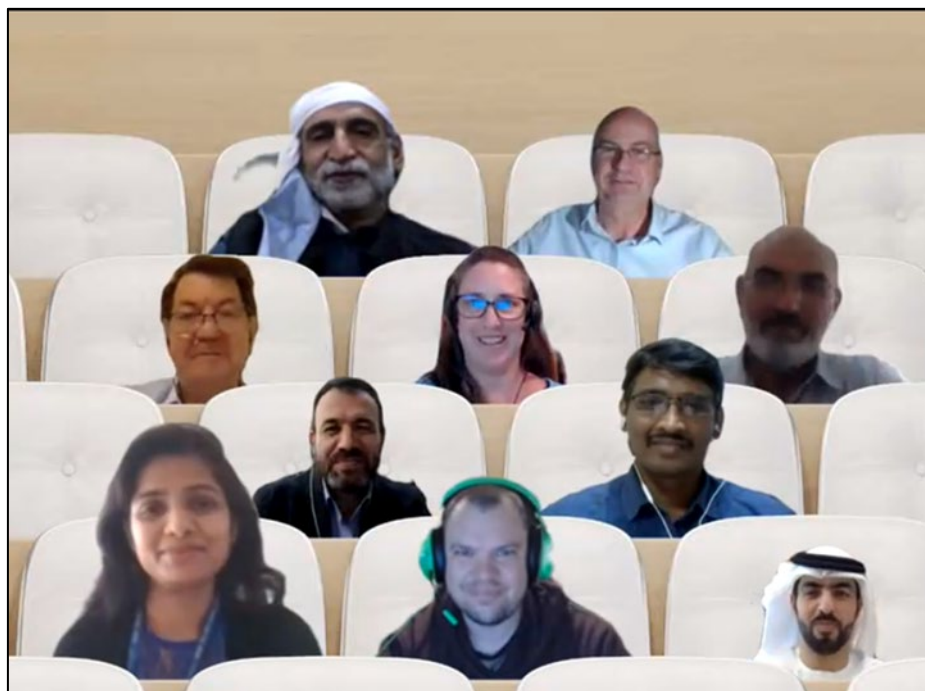
Dr. Andrey Babeyko (Germany)

UNESCO-IOC Representatives

Mr. Rick Bailey, ICG/IOTWMS Secretariat,
Ms. Nora Gale, ICG/IOTWMS Secretariat,
Mr. Ardito Kodijat, IOTIC

Observers

Dr. Robert Greenwood (Australia)
Mr. Pattabhi Rama Rao Eluri (India)
Mr. Padmanabham Jijjavarapu (India)
Ms. V. Sunanda Manneela (India)
Dr. Ali Khoshkholgh (Iran)
Dr. Mohammad Mokhtari (Iran)
Mr. Juma Al-Habsi (Oman)
Dr. Zaid Al-Habsi (Oman)
Dr. Juma Al-Maskari (Oman)
Mr. Ahmed Deif Gomaa Abdullah (Oman)
Mr. Ali Megahed (UAE)
Mr. Somneuk Swatteuk (Thailand)



Participants at the Intersessional Meeting of Task Team on Scientific Tsunami Hazard Assessment of the Makran Subduction Zone, Online Meeting, 9 November 2021

1. OPENING

1.1 Welcome and Meeting Logistics

Mr. Rick Bailey, Head of the Secretariat of the IOC-UNESCO Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) welcomed the task team members and invited experts to the intersessional meeting of the Task Team on Scientific Tsunami Hazard Assessment of the Makran Subduction Zone (TT-MSZ). He reported that the first phase of the UNESCAP-funded project on *Strengthening tsunami early warning in the North West Indian Ocean Region through regional coordination* (TTF-29) was completed at the end of October 2021 and the second phase of the project has been approved by the donor.

1.2 Opening Remarks

Dr. Mohammad Mokhtari, Chair of the Subregional Working Group for the North West Indian Ocean (WG-NWIO) reported on the UNESCAP-funded project on *Strengthening tsunami early warning in the North West Indian Ocean Region through regional coordination*. One of the project's key objectives is to better understand the risk knowledge of the Makran region based on scientific research. The key outcomes of Phase 1 include: (i) Availability of the latest scientific insights on the tsunami hazard from the Makran subduction zone as an input for risk assessment activities in participating countries; and (ii) Concept and inputs for a unified regional tsunami hazard map. Further, the outputs, performance indicators, and implementation strategy of Phase 1 were noted. In conclusion, he wished the best for all colleagues and friends attending the TT-MSZ.

Dr. Abdolmajid Naderi Beni, Acting Chair of the TT-MSZ, provided further opening remarks. Dr. Naderi Beni welcomed the task team members, invited experts, and UNESCO-IOC representatives and thanked everyone for their participation in the meeting. He recalled the contributions of the Secretariat including Mr. Rick Bailey and Ms. Nora Gale and gave special thanks to Dr. Juma Al-Maskari, the outgoing Chair of the Task Team. He noted the importance of all participants from different countries of the Makran region working together to better understand tsunami occurrences in the Persian Gulf and Gulf of Oman, which are hotspots for new research. Assessing the tsunami hazards that threaten coastal communities and infrastructure in the region, which have both increased over time, is important for community safety and land use planning. In conclusion he wished all participants a successful meeting.

1.3 Review and Adoption of Agenda

Mr. Rick Bailey presented the agenda, which was adopted without modification (refer to Annex 1). The list of participants is provided above, with more details provided in Annex 2.

1.4 Terms of Reference and Membership

Mr. Rick Bailey reviewed the terms of reference and membership of TT-MSZ.

The terms of reference include:

1. Draft an agreement document for real-time exchange between Member States of seismic/sea-level/GNSS data in the Makran Subduction Zone (MSZ)
2. Specify optimal number and configuration of seismic/sea-level/GNSS and other observing networks needed for real-time tsunami warning in the MSZ
3. Investigate and report on the credible maximum earthquake magnitude in the Makran Subduction Zone and define a strategy to develop a unified hazard map

4. Investigate and report on the seismicity of the Makran subduction zone as well as the potential impact of tsunamis in the Red Sea and Persian Gulf with a view to including those zones in the IOTWMS Area of Service if there is a threat
5. Review and report on the status of research into modelling of secondary non-seismic effects tsunamis in Makran for potential use in the IOTWMS

Members of the Task Team include representatives of the 3 TSPs (Australia, India, Indonesia), WG-NWIO Member States (India, Iran, Oman, Pakistan, United Arab Emirates, Yemen) and Observers from international institutions involved in research of MSZ (GFZ, GTM, UNESCAP, etc.).

2. UPDATES ON ACTIVITIES

2.1 UNESCAP Project

Mr. Rick Bailey provided an update on Phase 1 and the proposal for Phase 2 of the UNESCAP-funded project *Strengthening tsunami early warning in the North-West Indian Ocean region through regional cooperation*. The overall project goal of timely delivery of national tsunami warnings to at-risk coastal communities who are prepared to respond effectively, closely aligns with the UNESCO-IOC Tsunami Ready Programme. The project follows a programmatic approach consisting of three phases: (1) Hazard and risk assessment and national tsunami warning chain development, (2) Inundation and evacuation mapping capacity development, and (2) At-risk coastal community preparedness. Phase 1 is now completed and the funding for Phase 2 Objectives (2a and 2b) has been approved by the donor organisation UNESCAP. The project implementation philosophy is to empower participating countries (India, Iran, Pakistan, Oman, UAE) to develop a capacity, through a programmatic approach, based on best practices to review implement and maintain the processes and procedures required to warn and have at-risk communities effectively respond to the tsunami threat in the North-West Indian Ocean region.

During 2021, the project progressed through online communication and meetings due to COVI-19. Staff exchanges were also not possible due to COVID-19 impacts on travel and some staff have also been impacted personally by the virus. Model simulations have been run for all earthquake source scenarios and probabilistic calculations have produced the primary version of the Probabilistic Tsunami Hazard Assessment (PTHA) for the Makran region. Work has continued to improve data exchange through Memorandums of Understanding (MOUs), develop a better understanding of the seismicity of the regional to help improve future versions of the PTHA, take into consideration of hazard of atypical tsunami (non-seismic sources, e.g., submarine landslides, volcanos), and examination of the possibility of the tsunami threat in the neighbouring Persian Gulf and Red Sea.

The second phase of the project will undertake a gap analysis and develop guidance and capacity in tsunami inundation mapping and evacuation planning in the NWIO region. Additionally, the second phase will finalise the outstanding Phase 1 activities, which include: (i) Run propagation scenarios to complete version 1 of Makran PTHA; (ii) Exchange scientific staff between India and Germany/Italy for familiarisation with PTHA to enable hand over to the region; (iii) Hold (now virtual) scientific conference to share, exchange and discuss scientific results from the risk objective to review outcomes and broader uptake within each country; and (iv) Hold the third and final Standard Operating Procedure (SOP) workshop for National Tsunami Warning Centers (NTWCs), Disaster Mangement Organisations (DMOs, and the broadcast media to further develop, and in some cases finalise and test SOPs for all links in the national tsunami warning chains of each participating country. A schedule of the Phase 2 project activities was presented.

Dr. Andrey Babeyko asked about the inundation assessment. Mr. Bailey replied that a gap analysis will be undertaken to determine each country's capabilities for inundation mapping. The inundation training will be undertaken during the proposed third phase. Dr. Andrey Babeyko suggested conducting an inundation pilot study, for example in Karachi, and then try to extend the practice into other localities.

Dr. Mohammad Mokhtari suggested a regional modelling approach with Member States contributing data to a broader model. Mr. Bailey noted that the planned scientific conference should consider such ideas and recommend a strategy for further developments and regional uptake of best practices.

Dr. Mokhtari further noted that the available bathymetry and topography data will influence the resolution and accuracy of the inundation models.

2.2 Probabilistic Tsunami Hazard Assessment (PTHA)

Dr. Andrey Babeyko reported on progress of the Makran PTHA, which includes the Arabian and Red Seas and the Persian Gulf. The concept for the assessment was initially discussed during the *Expert Consultation on Scientific Tsunami Hazard Assessment of the Makran Subduction Zone* held in Kish Island, Iran, March 2019. An example from TSUMAPS NEAM was used to illustrate the hazard assessment at points along the coast, which produced a ‘cloud of predictions’ with different probabilities and percentiles. For the Makran PTHA study a seismic source model was developed for the Arabian plate considering both plate interface and crustal earthquakes. A non-linear approach has been undertaken for the shallow basins in the Persian Gulf and Red Sea, while a linear approach has been undertaken for the deep-water Arabian sea. The special case of wave propagation through the Strait of Hormuz into the Persian Gulf has also been considered.

Dr. Babeyko noted that most PTHA-construction blocks are already prepared and available. However, the computations need accelerating and a ‘hackathon’ was suggested to speed up the PTHA assessment. Furthermore, he proposed that leadership from within the Makran region would be beneficial.

Dr. Mokhtari asked when the report will be available for circulation. Dr. Babeyko noted that it depends on how quickly progress can be made. If a ‘hackathon’ can be scheduled, the report will be available much sooner.

Dr. Mokhtari suggested inclusion of secondary effects such as splay faulting in future versions of the model. Further, Dr. Babeyko explained that a pilot study of regional tsunamis generated from outside of the Makran subduction zone is required to determine the influence of secondary effects from atypical sources. However, this is beyond the scope of the current project.

Mr. Ameer Hyder asked if predefined faults have been included in the PTHA. Dr. Babeyko responded that the predominant focal mechanism in the region is being included in the probability density functions of this study. This contribution is being undertaken by Ms. V. Sunanda Manneela. Mr. Hyder offered to collaborate with Ms. Manneela on this.

The idea of a ‘hackathon’ involving INCOIS researchers spending two-weeks running the models from Europe (Germany or Italy) was discussed. Additionally, the group discussed the benefits of alternative leadership from within the region. Both ideas will be further explored following this meeting.

2.3 Data Collection and Agreement for Data Exchange

Dr. Mohammad Mokhtari reported on data collection and agreement for data exchange. He suggested that a specific group be convened to:

1. Identify the most optimum locations, numbers for seismic, GPS, and tide gauge stations
2. Identify the most optimal TSP centres and how the data can be shared in near real-time with them
3. Report on the above findings and finalise the country data exchange agreements
4. Promote regional instrumentation for tsunami early warning

Additionally, the use of seismic data from global network operators (e.g., CTBTO) and nearby countries was encouraged for tsunami monitoring in the Makran region, noting that access to CTBTO data was previously arranged by IOC-UNESCO for National Tsunami Warning Centres soon after the ICG/IOTWMS was established

Dr. Issa El-Hussain updated the meeting that Sultan Qaboos University has developed a template agreement for data sharing and circulated it prior to the COVID-19 pandemic. Recently Pakistan and Oman signed an agreement for bilateral data exchange. Oman is currently exchanging data with Iran and UAE and working on an agreement with India. The bilateral agreement template has been approved by the relevant legal ministry (or other entity) in each country and could be shared and adopted for countries to use.

Dr. Robert Greenwood presented a seismic station map for the North-West Indian Ocean region showing data from six stations (mainly CTBTO) that TSP-Australia has access to. Ms. Manneela noted that India currently has access to only three seismic stations in the region. Dr. El-Hussain noted that there is no CTBTO station in Saudi Arabia. Dr. Greenwood expressed a need for TSP Australia to acquire data from more regional stations.

Dr. Mokhtari noted that a further five seismic stations are going to be installed in Iran by Hormozgan University. It is the intent that the data can be shared for tsunami monitoring.

Mr. Bailey noted that a system is required to keep track of the available seismic networks and operational stations.

The group discussed how the TSPs can access data from Makran countries for use in tsunami monitoring. It was suggested that the TSPs could also follow the bilateral data exchange model.

2.4 Seismicity of the Makran Subduction Zone

Dr. Issa El-Hussain presented on the seismicity of the Makran subduction zone. The Arabian Peninsula is subject to near-field tsunamis such as the 1945 M8.1 event off the coast of Pakistan. The Makran subduction zone extends 900-1,000 km between the Zendan Fault to the west and the Ornach Nai Fault to the east. The seismicity of the Makran subduction zone is low in comparison to other subduction zones of the world, with most of the seismicity contained within its eastern segment. The relatively quiet nature of the west Makran subduction zone remains the subject of ongoing geological and geophysical research.

Dr. El-Hussain noted that training in tsunami hazard modelling and assessment will be held at Sultan Qaboos University in February 2022. The training will be 1-week duration and face-to-face. Mr. Ameer Hyder asked is there is a possibility of online seismology training organised by Sultan Qaboos University to which Dr. El-Hussain said he would investigate.

Dr. Naderi Beni shared a photo from the Makran coast, which showed deformation and systematic faults along coasts of Iran and Pakistan. The impacts of the Makran subduction zone on shaping the coastline could be addressed in future studies and land use planning initiatives. Dr. El-Hussain and Dr. Mokhtari were intrigued by the image and agreed that it would be interesting to follow up.

2.5 Paleo-tsunami Research in the Makran Subduction Zone

Dr. Mohammad Mokhtari provided an update on paleo-tsunami research in the west Makran Subduction Zone. Dr. Mokhtari is leading a UNESCO International Geoscience Programme (IGGP) project to determine past tsunamis by a multidisciplinary analysis based on new mapping, coring, trenching, and sampling of data in Iran, Pakistan and Oman. The project will run over 3-years and is currently in the first of three phases. It is hoped the results will provide reoccurrence intervals of tsunami and maximum magnitude of events along the west Makran subduction zone. Field visits to identify potential study locations were carried out during July and August 2021. Preliminary investigations have identified slumps of sediment within the coastal stratigraphy and imbricated coastal boulders, which could be related to past tsunami events along the west Makran Subduction Zone. Twenty trenches at seven localities are planned for the next step.

Mr. Hyder noted that training of people in each participating country would enhance regional cooperation. Dr. Mokhtari replied that “on-the-job” training at the trench sites is incorporated into the project, especially for young emerging scientists. This will commence in mid-2022.

Dr. Naderi Beni mentioned the relationship between climate change and the increase in tsunami in the Gulf of Oman. The basin is detrital and receives a huge volume of sediments from run-off and stream flow during the monsoon. Consequently, there's the potential under climate change for an increase in the sediment accumulation rate that could result in more slope failure triggered tsunamis.

Further, Dr. Naderi Beni drew attention to the merit of a joint international research expedition involving researchers from Makran countries to further characterise the west Makran Subduction Zone. Mr. Hyder expressed the support of Pakistan.

2.6 Atypical Tsunami Sources

Mr. Patanjali Kumar Chodavarapu briefed on atypical tsunamis with regards to modelling in the Makran region. The Indian National Centre for Ocean Information Services (INCOIS) is commencing modelling of tsunami induced by landslides in shallow water. Benchmark models will be conducted in the Persian Gulf and Red Sea. The landslide unit sources are under construction in these areas. Current thinking is that the tsunami modelling will be performed using either HySEA or GeoCloud.

Dr. Naderi Beni presented on atypical tsunamis in the Persian Gulf. He is of the opinion that the Persian Gulf is not capable of producing large earthquakes. However, there is apparent historical evidence of a deadly and damaging tsunami in the ancient port of Siraf in 1008AD. In March 2017, there was a meteotsunami within the Persian Gulf in Dayyer, Iran. Moreover, coastal cliff failures could be responsible for tsunami, and may be responsible for the early 11th century event in Siraf. There are no detailed bathymetry maps of the Persian Gulf, however, sink holes have been identified that could possibly generate tsunami.

Dr. El-Hussain asked about the area of the sink holes. Majid replied that one in the Strait of Hormoz is 4km in diameter with the deepest part ~200 m deep.

Mr. Bailey commented that atypical tsunamis are a growing area of interest. Under TOWS-WG a team is working on how to characterize, forecast and warn of these events. The Kyoto Landslide Consortium 2020 is also investigating both terrestrial and submarine landslides. Within the framework of the UN Ocean Decade potential new tsunami warning technologies are being investigated. Mr. Bailey suggested that next year [2022] would be a good opportunity to bring these groups together.

Dr. Greenwood noted that volcanic eruptions are perhaps the easiest source to identify due to the volcanic plume. Prior to the tsunami on 22 December 2018, Anak Krakatoa had been erupting for about 3 months with similar sized eruptions prior to the tsunami generating event.

Mr. Bailey asked the group if a symposium on the atypical source tsunamis is needed. The group agreed that this was a good idea. He further noted that a paper on atypical tsunamis will be presented to the TOWS-WG meeting in February 2022.

Ms. Maneela suggest a small team could identify the regions exposed to atypical tsunami threats. Further, a database could be constructed of past atypical tsunami events in the Indian Ocean region. Dr. Naderi Beni commented that the mud volcanos within the Gulf of Oman could be a potential tsunami source.

2.7 Tsunami Hazard in the Persian Gulf and Red Sea

Mr. Patanjali Kumar Chodavarapu noted that the datasets and parameters for the Persian Gulf and Red Sea PTHA are under development. A finite element mesh has been constructed using data from the General Bathymetric Chart of the Oceans (GEBCO). Using course resolution, the tsunami propagation can be performed in under one minute. The datasets shared by Dr. El-Hussain and Omani colleagues for the source zones are being considered. The finite element mesh has been constructed and the source parameters are under construction at INCOIS. Full scale simulations will be modelled using ADCRIC.

Ms. Maneela explained that the Persian Gulf and Red Sea analyses contribute to the Makran PTHA work undertaken as a contribution to the UNESCAP project. Therefore, this work will be included in the Makran PTHA report.

3. OTHER BUSINESS

There was no other business addressed during the TT-MSZ meeting.

4. NEW RECOMMENDATIONS AND ACTIONS

Recommendation: Continue the Task Team on Scientific Tsunami Hazard Assessment of the Makran Subduction Zone into the next inter-sessional period.

Recommendation: Incorporate regional training as part of the west Makran Subduction Zone ICGP project led by Dr. Mokhtari.

Recommendation: Consider a regional expedition to map marine sedimentation in the west Makran Subduction Zone to help better determine the associated tsunami hazard.

Recommendation: Secretariat to (co-)organise a symposium on the atypical source tsunamis.

Action: Secretariat to investigate the logistics of a hackathon to progress the PTHA modelling for the Makran region.

Action: Secretariat to identify a person who could lead the PTHA study from within the Makran region.

Action: Dr. Issa El-Hussain to share the bilateral agreement for data sharing with the Secretariat for sharing with other Makran countries and the TSPs.

Action: Secretariat to develop a system to keep track of the available monitoring networks.

Action: Set up a task force to investigate the optimal tsunami monitoring network design in the Makran region (Mohammad Mokhtari, Issa El-Hussain, Sunanda Manneela, Pakistan (PMD) representative, Australian (GA) representative).

Action: Dr. El-Hussain to share information on the upcoming tsunami training at SQU with the Secretariat and investigate the possibility of Sultan Qaboos University organising an online seismology training session.

Action: Compile a hazard catalogue of atypical tsunami sources in the Indian Ocean (task force activity).

5. SUMMARY AND CLOSING

Dr. Abdolmajid Naderi Beni thanked all Task Team members, invited experts and the Secretariat for their participation and hard work. He hoped our collaboration will help us to better characterise the tsunami sources in the Makran region.

Mr. Rick Bailey thanked everyone for their ongoing collaboration. The funding from UNESCAP is helpful in catalysing activities, but much work remains to be done within the Member States. He thanked all for their efforts to date to help at-risk communities. In conclusion, Mr. Bailey noted that there is much more work for the Task Team to be undertaken.

Dr. Juma AlMaskari, the immediate past Chair of TT-MSZ, provided a statement that was delivered by Mr. Bailey. Dr. AlMaskari observed that from looking in from the outside now it was obvious that much hard work is being done by the Task Team. He encouraged the group to keep up the momentum and the fruitful work.

The intersessional meeting of ICG/IOTWMS TT-MSZ was officially closed at 10:00 UTC by Mr. Bailey.

ANNEX 1: AGENDA

**ICG/IOTWMS Task Team on
Scientific Tsunami Hazard Assessment of the Makran Subduction Zone**

9 November 2021

Acting Chair: Dr. Abdolmajid NADERI BENI

Time: 06:00 –09:30 UTC

<p>06:00 –06:30 UTC Moderator: Nora Gale</p>	<p>1. Opening</p> <p>1.1 Welcome and Meeting Logistics (5min) <i>Mr. Rick Bailey (Head of ICG/IOTWMS Secretariat)</i> <i>Ms Nora Gale (ICG/IOTWMS Secretariat)</i></p> <p>1.2 Opening Remarks (10min) <i>Dr. Mohammad Mokhtari (NWIO-WG Chair)</i> <i>Dr. Abdolmajid Naderi Beni (TT STHMSZ Chair)</i></p> <p>1.3 Review and Adoption of Agenda (5min) <i>Dr. Abdolmajid Naderi Beni (TT STHMSZ Chair)</i></p> <p>1.4 TT STHMSZ Terms of Reference and Membership (10min) <i>Mr. Rick Bailey (Head of ICG/IOTWMS Secretariat)</i></p>
<p>06:30 – 8:30 UTC Moderator: Rick Bailey</p>	<p>2. Updates on Activities and Future Plans</p> <p>2.1 UNESCAP Project (10min + 5min discussion) <i>Mr. Rick Bailey (Head of ICG/IOTWMS Secretariat)</i></p> <p>2.2 Probabilistic Tsunami Hazard Assessment (PTHA) (15min + 15min discussion) <i>Dr Andrey Babeyko</i></p> <p>2.3 Data Collection and Agreement for Data Exchange (10min + 5min discussion) <i>Dr. Mohammad Mokhtari</i></p> <p>2.4 Seismicity of the MSZ (10min + 5min discussion) <i>Dr. Issa El-Hussain</i></p> <p>2.5 Paleo-tsunami research in the MSZ (10min + 5min discussion) <i>Dr. Mohammad Mokhtari</i></p> <p>2.6 Atypical tsunami sources (10min + 5min discussion) <i>Mr. Patanjali Kumar Chodavarapu</i></p> <p>2.7 Tsunami hazard in the Persian Gulf and Red Sea (10min + 5min discussion) <i>Mr. Patanjali Kumar Chodavarapu</i></p>
<p>08:30 – 0840 UTC</p>	<p><i>Break</i></p>
<p>08:40 – 09:10 UTC Moderator: Dr. Abdolmajid Naderi Beni</p>	<p>3. Other Business (30min)</p>
<p>09:10 – 09:25 UTC Moderator: Nora Gale</p>	<p>4. Review of New Recommendations and Actions (15 min) <i>Mr. Rick Bailey (Head of ICG/IOTWMS Secretariat)</i></p>
<p>09:25 – 09:30 UTC Moderator: Nora Gale</p>	<p>5. Summary and Closing (5min) <i>Dr. Abdolmajid Naderi Beni (TT STHMSZ Chair)</i> <i>Dr. Juma Al-Maskari (Distinguished Guest)</i> <i>Mr. Rick Bailey (Head of ICG/IOTWMS Secretariat)</i></p>

ANNEX 2: DETAILED LIST OF PARTICIPANTS
ICG/IOTWMS Task Team on
Scientific Tsunami Hazard Assessment of the Makran Subduction Zone
9 November 2021

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