Expression of Interest for a DFG-Round Table Discussion on

Near- and Onshore Tsunami Effects
- Knowledge Base Generation and Model Development -

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1. Position of the Problem, Motivations and Framework

The 2004 Indian Ocean Tsunami has highlighted inherent vulnerabilities of the world's coastal zones. The most striking results and implications of this disaster may be summarized as follows:

(i) ***Enormity and scale of the impact*****:** Both have impressively been illustrated by the media, the published assessment reports (e.g. UNEP, 2005; ASCE, 2005; JSCE, 2006) as well as by the satellite "before-and-after-images". This implies an immense challenge for science, engineering and policy as well as a unique opportunity to deploy coordinated activities toward increasing preparedness and resilience of coastal communities against environmental extremes and shocks.

(ii) ***Non-preparedness for extreme threats***: No country was prepared to adequately face such a devastating extreme event at such an enormous scale. This implies not only a huge research challenge for the prediction of extreme hazards, but also for the management of similar future risks before during and after the occurrence of such extreme event.

(iii) ***Insufficient knowledge of "before-state" of impacted coastal areas:*** The actual state of bathymetry, shoreline, onshore topography and ecosystems just before the tsunami event were not sufficiently documented. This implies that serious difficulties will be encountered in the assessment of the tsunami impacts. Moreover, the use of the latter to validate any hindcast modelling will be rather questionable.

(iv) ***High spatial variability nearshore:*** Tsunami height and tsunami effect have shown significant variability from place to place along the coastline (Figs. 1 & 2), implying (a) that no model exists yet to reliably predict both nearshore tsunami height and its effect at every place along the coast and around the islands and (b) that there is a serious lack of understanding of

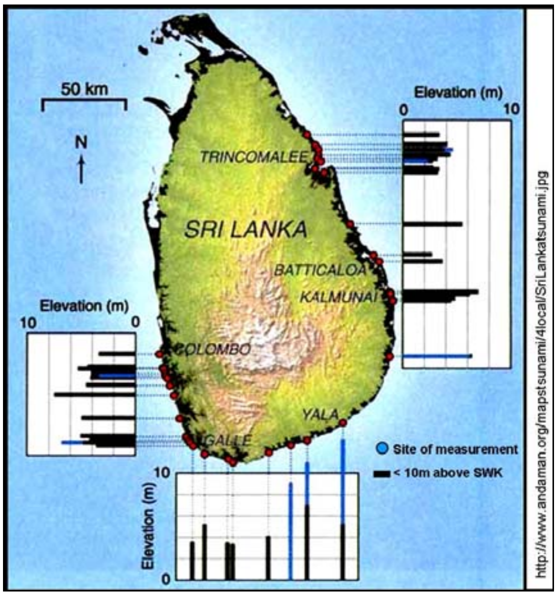


Fig. 1: Tsunami heights (black) and run-up (blue) measurements in Sri-Lanka (Liu et al., 2005)

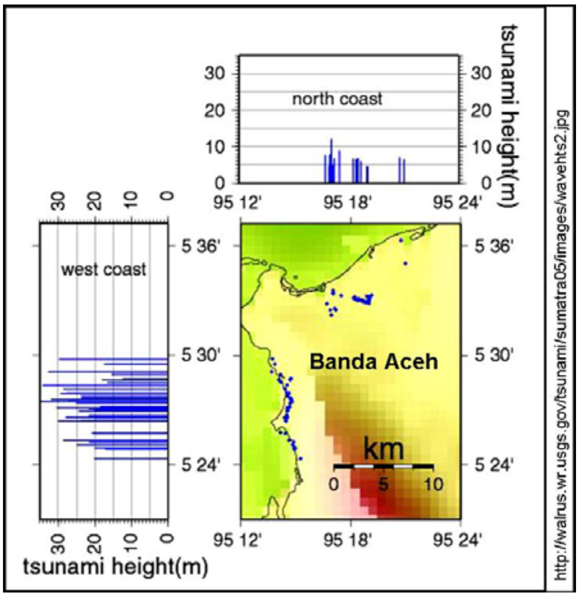


Fig. 2: Tsunami heights measured in Sumatra (USGS, 2005), http://walrus.wr.USGS.org.

the complex interactions between the water-borne energy, the seabed topography and the shoreline configuration as well as between generation mechanisms and tsunami parameters.

(v) ***High spatial variability onshore:*** Tsunami run-up and inundation distance have been shown to be very variable from place to place along the coastline (Figs. 3 and 4), implying that (a) no model exists yet to reliably predict tsunami run-up height and distance onshore and

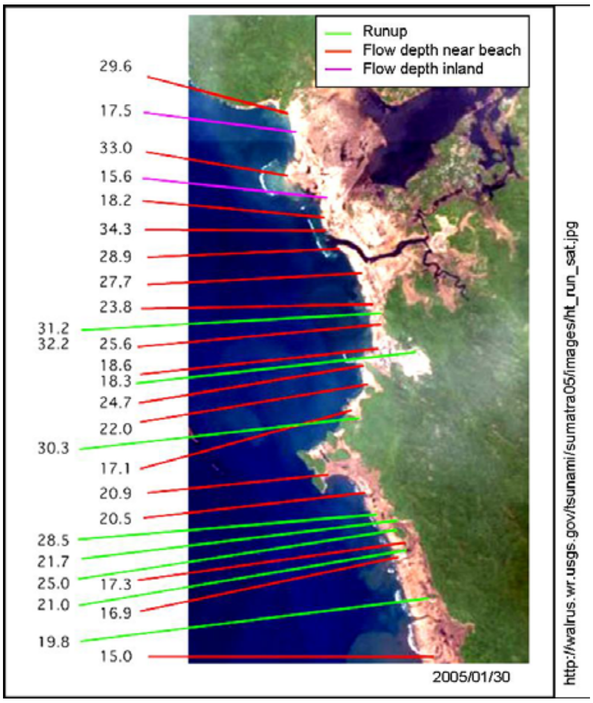


Fig. 3: Tsunami run-up and flow depth in Sumatra (USGS, 2005), http://walrus.wr.USGS.gov

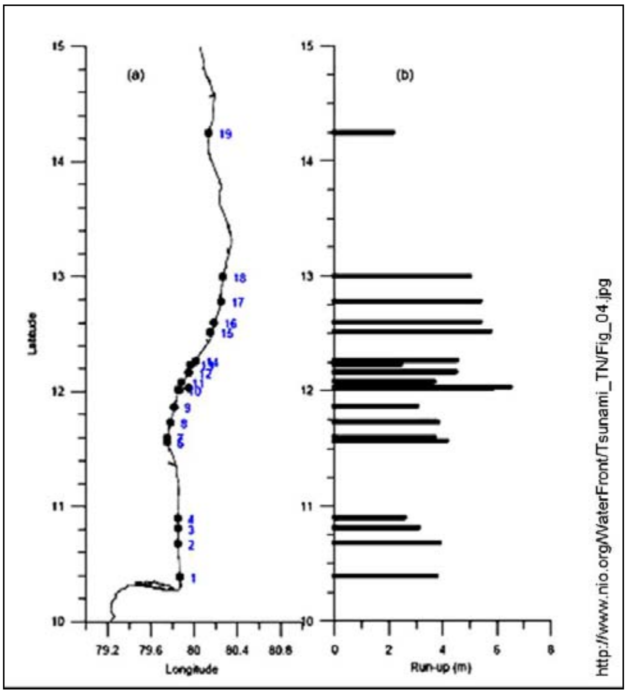


Fig. 4: Run-up in Tamil Nadu, India. (Jayakumar et al, 2005) in www.nio.org/Waterfront/TsunamiTN/fig04.jpg.

(b) horizontal coastal mapping based on distance from Mean High Tide Line will be limited if no reliable model will be made available in the near future.

(vi) ***Insufficient rigour in tsunami impact assessment:*** The report of UNEP (2005) and similar "Rapid Assessment Reports" have often been inaccurate in their analysis and uncritical in the use of local anecdotes and interviews. The uncritical citations of the latter, together with some papers published in the scientific literature, have greatly contributed to perpetuate some myths – to some extent even within the scientific community. Among these myths the most pervasive are those related to the widely exaggerated effectiveness of coastal forests and coral reefs to reduce damage to coastal communities. The idea that healthy coastal forests and coral reefs will provide significant protection against tsunami is a beautiful idea, but it has to be checked quantitatively and systematically with the scientific rigour it deserves, because the results are vital for risk assessments and the allocation of resources to mitigate tsunami.

To avoid similar disasters in the future, most research efforts have been directed toward a rapid implementation of early warning systems, but less to structural mitigation measures. In fact, early warning represents a primary component of disaster mitigation. However, it will help effectively preventing loss of life and reducing economic impacts only if it is incorporated into an integrated framework of risk analysis and management of coastal zones.

Such an integrated risk analysis and management framework is being developed for flood hazards within the 5-year EU-Integrated Project "FLOODsite" (2004-2009). Since the latter is based on the risk source-pathway-receptor concept, and since it includes both structural and non-structural risk mitigation measures before, during and after the hazard event (Fig. 5), the framework itself as well the associated prospective integration tools and methodologies can easily be adapted to tsunami and further coastal hazards. For this purpose, some applied research and development efforts would certainly be required[(*)].

Due to the peculiarities of tsunami as compared to storm surges and waves, considerable basic research[(**)] efforts will be required at the pathway and receptor levels as well as at the source level (Fig. 5).

[(*)] outside DFG-funding policy
[(**)] within DFG-funding policy

In fact, the 2004 Tsunami has revealed several gaps in the scientific knowledge and several weaknesses of the present models for tsunami generation as well as its near- and onshore propagation, including the effects of various coastal features (bottom topography, coastline shape, etc.) and various man-made (coastal structures, buildings, etc.) and natural (beaches, dunes, forest vegetation, etc.) barriers.

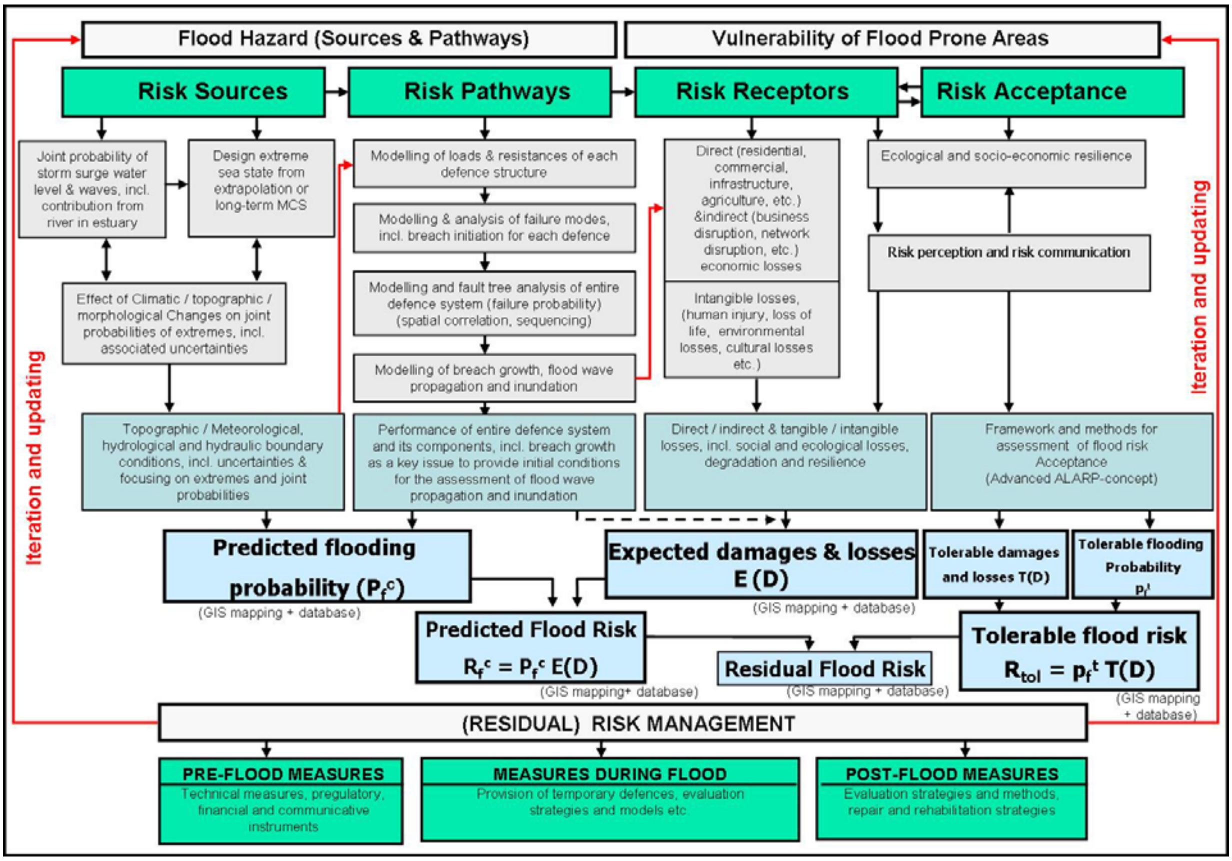


Fig. 5: Integrated Risk Analysis and Management Framework for Coastal Floods Induced by Storm Surges (Oumeraci, 2004)

One of the key peculiarities of a major tsunami is that it is a too difficult event to predict and a too strong hazard to control. Despite this apparent uncontrollability there are – beside non-structural measures such as early warning, education, evacuation and regulation strategies – also structural measures which can be taken to prevent loss of life and to minimize economic, environmental and cultural losses. For this purpose, a “Divide-and-Rule Defence Strategy” has been proposed (Fig. 6). The latter is based on a multi-defence line composed of man-made structures and natural barriers which may extend from offshore (e.g. reef structures) to the hinterland (e.g. mobile defences for critical facilities).
The type, number and size of the required defence lines/structures can be tailored to the actual local conditions (coastal morphology, climate, local availability of construction materials and technologies, etc.) as well as to the actual vulnerability of the considered flood prone area.

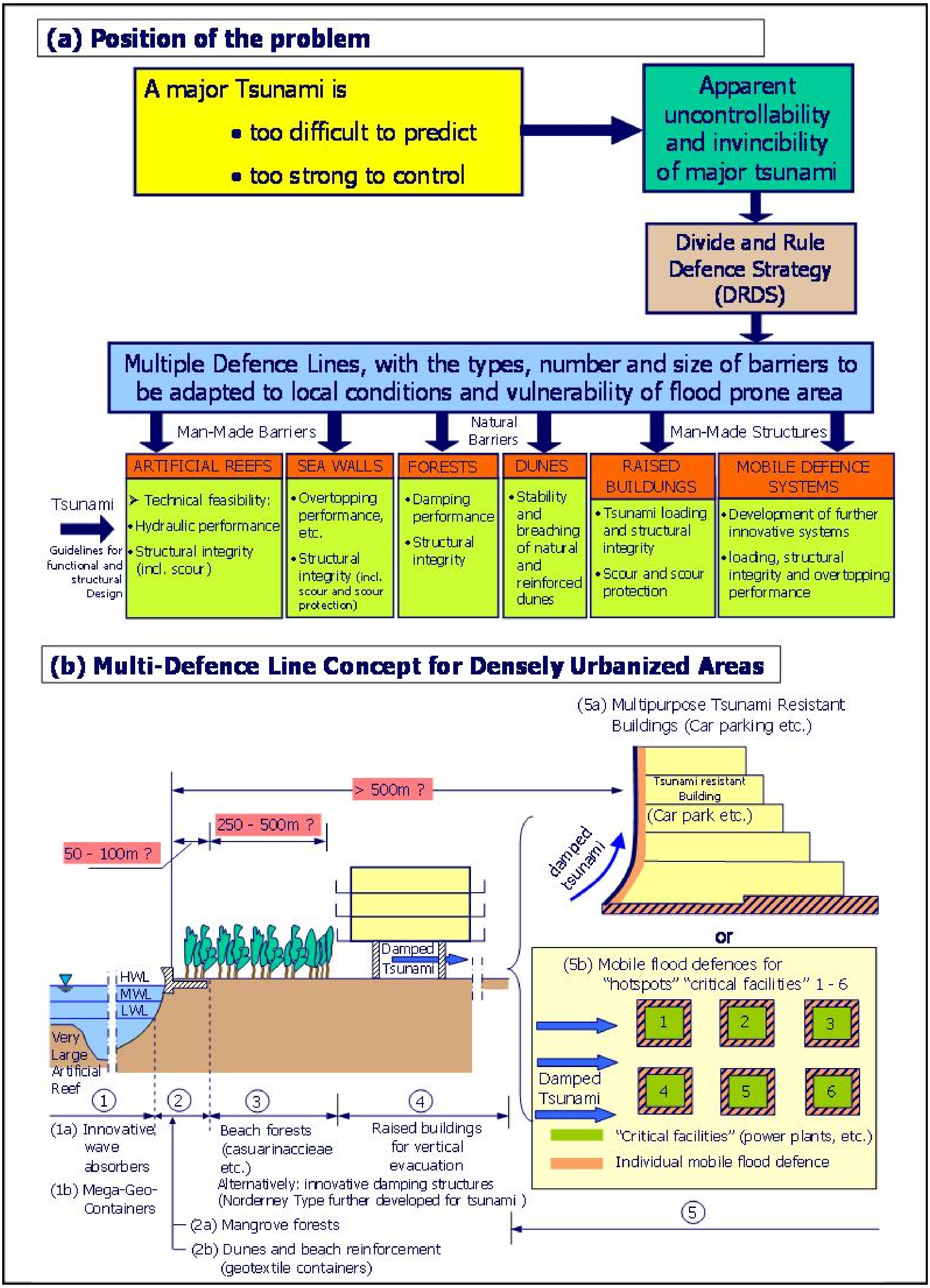


Fig. 6: Divide-and-Rule Defence Strategy Against Major Tsunami as Proposed by Oumeraci (2006)

2. Knowledge Gaps Related to Near- and Onshore Tsunami Effects

The reliable modelling of tsunami propagation and tsunami effects in:

- ► **nearshore areas** with complex seabed topography and morphology, including natural and man-made barriers (reefs, breakwaters, etc.) as well as complex shorelines, including caps, bays, lagoons and estuaries;
- ► **onshore areas** with complex morphology including natural barriers (e.g. dunes, coastal forests) and man-made structures (seawalls, dikes, etc.)

is extremely important for the prediction of

(i) tsunami height distribution along the shoreline,
(ii) tsunami run-up distribution along the onshore area, including inundation depths and distances from the shoreline,
(iii) bottom shear stress and the degree of turbulence which are crucial for the prediction of morphological changes,
(iv) wave forces on man-made structures and natural barriers near- and onshore, and
(v) debris flows and resulting forces on obstacles.

Moreover, obtaining a detailed insight into the physical processes involved in the interaction of tsunami with natural barriers and man-made structures is essential for the prediction of the hydraulic performance (reflection, transmission, dissipation) of these barriers and structures, including the prediction of their loading and structural integrity. The fact that many natural and man-made obstacles encountered onshore by the tsunami are moveable (vegetation, debris, etc.) makes these predictions much more complicated. In view of the current scientific knowledge most of the aforementioned issues cannot or can be only insufficiently be predicted by the existing models.

2.1 Primary Sources of Tsunami Threats

All types of tsunami threats to human life, human infrastructure and coastal ecosystems primarily originate from the three following sources:

2.1.1 Flooding

Depending on the type of the wave running up the shore (surge, on turbulent bore) - the wave form onshore being essentially determined by the incident tsunami wave parameters and the beach morphology - the tsunami effects onshore will significantly vary. Apparently, turbulent bores represent the most violent and devastating tsunami form onshore. However, a surging tsunami may result in larger inundation distances and flow depths, and thus in more stagnation of salt water which might pollute groundwater and threat terrestrial vegetation and organisms.

The operational models used to date are 2DH-NSW (Non-Linear Shallow Water) and BOUSSINESQ-type models which are depth-averaged and can therefore not always

(i) provide the wave height distribution correctly along the coastline for a complex nearshore topography

(ii) tackle correctly with all the processes involved in the interactions between tsunami and structures, including the subsequent loads.

Therefore, tsunami impact forces and overtopping on nearshore and onshore structures, as well as wave run-up and overwash can still not be reliably predicted. For the hydraulic performance of natural and man-made barriers in terms of wave damping and run-up reduction, energy dissipation sources (wave breaking, eddy viscosity) are introduced as sink terms in the depth averaged model. Detailed 2D- and 3D flow models based on Reynolds Averaged Navier-Stokes-Equations (RANSE) are available and capable to tackle in principle correctly with all the above mentioned issues and processes. At present, however, they are not feasible in operational terms due to the computational time required.

Whether coupling 2DH-models (farfield) and 3D-RANSE-models (nearfield) represents now the only solution or other alternatives should be considered, still remains an unsolved problem. The answer of this question should be a key issue of the discussions at the DFG-Round Table, since it has cruicual implications on further research and cooperation issues.

The development of novel flood defence measures, their experimental testing and optimisation through numerical modelling might also represent an important discussion issue.

2.1.2 Backwash Flow

The receding water was one of the most serious threats in the 2004 Tsunami as it dragged people and considerable amounts of natural materials (e.g. sediment, vegetation) and man-made debris into the sea. Reliable models are needed to predict the backwash flow and the associated effects and impacts taking into account different onshore topographies and configurations as well as the presence of different types and sizes of obstacles. Innovative countermeasures to reduce the impact of the drag flow should also be developed, experimentally tested and numerically optimised.

2.1.3 Erosion, Transport and Deposition of Sediments and Debris

Local scour around man-made structures and natural obstacles (e.g. trees) as well as larger scale erosion have considerably contributed to the damages caused by the 2004 Tsunami. The impact of debris flow has been found to affect both human life and infrastructures, while deposition of sediments and debris has affected both marine and terrestrial ecosystems. The degree of impact strongly depends on the basic types of shoreline, the local height of the tsunami, the urbanisation density and the level of protection. ***Steep rocky shore*** has generally proved resilient to tsunami. ***Sandy shore*** has proved very sensitive to erosion and protection by natural barriers (e.g. reefs, forests) did not always prove efficient. ***Coastal reclaimed land, including harbour areas*** have generally been eroded significantly, because protective structures designed for storm waves were heavily overtopped and did not withstand tsunami. ***Mudflats, estuaries and lagoons*** have significantly been eroded, particularly when local tsunami height was too high for natural barriers to provide sufficient protection. As a result in channel deepening, opening or closing of lagoon mouths, up travelling of saltwater up to more than 5 km inland and enlargement of lagoons with dramatic salinity increase occurred. The knowledge related to tsunami induced bottom stress and other tsunami induced processes affecting the erosion, sediment transport and debris flow is too poor to come up in the very near future with any reliable models to predict local scour, large-scale erosion and debris flow under various tsunami and coastal morphological conditions.

2.2 Tsunami Defence Barriers

Efficient early warning, evacuation and regulation strategies as well as further non-structural mitigation measures represent of course vital components of the entire tsunami defence system, but in many circumstances – especially in the case of densely populated areas and highly vulnerable coastal zones – structural measures must be considered to prevent loss of life, and to minimize economic, environmental and cultural losses. For this purpose, and in view of the apparent invincibility of major tsunamis, a multiple defence line will be required, including both man-made structures and natural barriers which may extend from offshore (reef structures) to the hinterland (mobile defence for critical facilities) over the inshore and onshore zones as exemplarily shown in Fig. 6. As mentioned in Section 1 above, the type, number and size of the defence lines can be tailored according to the local conditions associated with the practical feasibility of the selected defence structures and barriers.

A reliable assessment/prediction of the tsunami damping effectiveness of these natural and man-made structures, including their structural integrity when subject to major tsunamis, is not only crucial for any optimisation of their risk-based design and management. Moreover, the presence of these near- and onshore structures will introduce more complexity -and thus more requirements- for the tsunami models which are needed for tsunami inundation mapping, land use planning and regulations.

It seems therefore meaningful,

(i) to briefly review the performance of both natural and man-made barriers during the 2004 Tsunami and

(ii) to identify the implied knowledge gaps and the priority research needs.

2.2.1 Natural Tsunami Barriers

(a) "Offshore" Barriers

These particularly include coral reefs, sand and small barrier islands. A plethora of anecdotal reports in the media reinforced by preliminary field surveys and the results of "Rapid Assessment Reports" (e.g. UNEP, 2005) have suggested the likely evidence that coastal areas protected by healthy coral reefs did experience none or much less damage than those where the reefs were degraded or absent. Some papers also emerged in the scientific literature which have also greatly contributed to relate the experienced tsunami damage directly to coral mining (e.g. Fernando et al, 2005).

Actually, the hydraulic performance of these offshore barrier and their structural integrity is difficult to asses due to the unknown actual state just before tsunami as well as to the lack of reliable models. Even, if one will succeed to provide a clear field evidence that natural reefs have indeed proved effective in the protection against the 2004 Tsunami, it will still remain unclear, whether this will be true for larger periods of the tsunami (e.g. T = 20-60min.).

Therefore, a reliable hydrodynamic model is needed to assess/predict both the damping effectiveness and the structural integrity of coastal reef/offshore barrier to major tsunami over the full range of wave periods (up to 60min.) as a function of geomorphology and material parameters. The parameterization from the hydrodynamic and structural view point as well as the development/validation of the models will be performed by coastal engineers/hydrodynamists. The geomorphological and material inputs as well as field data (including paleo-tsunami) must be provided by geoscientists. This also includes the examination of the geomorphology of islands (and associated reef systems) to determine the nature and extent of any structural changes due to tsunamis. Moreover, barrier islands and other narrow landforms protecting the mainland against storm surges may also experience breaching during major tsunamis. Such a breaching occurred for instance during the 2004 Tsunami at Rahfathi Island in the Maldives (Fig. 7).

(a) Before 2004 Tsunami

(b) After 2004 Tsunami

Fig. 7: Breaching of Rahfathi Island, Maldives (Gunn et al, 2005)

The hydrodynamic and geomorphodynamic processes which have resulted in the breaching of such narrow islands and further similar landforms are still unknown and reliable models to hindcast or predict such a breaching are still not available. The processes associated with the extensive erosion suffered by the ends of such islands –even they did not breach– are also still unknown.

(b) Onshore Barriers

These barriers particularly include mangrove forests, beach forests and sand dunes.

Even, where ***forest vegetation*** was resilient, dense and wide enough the tsunami damping effectiveness was actually much lower than the present models would predict and than numerous anecdotal reports and rapid assessment reports have suggested. Particularly the UNEP-report (2005) and IUCN-reports (2005) were more ambivalent about the tsunami damping effectiveness of forest vegetation and presented empirical data which contradicted the conclusions of the original "Wetlands International Report (2005)". In fact, while the former concluded that:

> *"…mangrove forests and other coastal vegetation provided protection from the impact of the tsunami"*

the latter, however, concluded that:

> *…in high energy situations such as in Aceh province complete loss of mangroves occurred, indicating that in extreme events very little mitigation may be possible" and that "…mangroves were carried by the waves up to*

> *three kilometers inland; this included mangroves that were in relatively good conditions…".*

Actually, the damping performance significantly varied from place to place, depending on (i) the sloping nature of the shore (ii) the robustness, nature, density and width of the forest vegetation and (iii) the nature and resilience of substrata. In fact, where vegetation was low lying in non-resilient substrata, it was completely removed and large amounts of soil were carried out to the sea. Based on the results of the surveys available so far, no conclusive assessment can be made about the tsunami damping performance of coastal forests and their structural integrity when subject to major tsunami.

A brief review of the scientific literature shows that the results predicted by available analytical and numerical models for the tsunami damping performance of coastal forests are not only contradictory, but also very incomplete and inconclusive regarding the dissipation performance of forest vegetation. A better understanding of the process involved in the multiple interaction of tsunami with the forest components is first needed before embarking into any sophisticated numerical modelling. Second, a proper parameterization of typical mangroves and beach forest from the view point of hydraulic resistance is also required.

A tiered modelling approach should then be considered in the development of models which can describe the dissipation performance of any coastal forest as a function of its density, width and tree parameters. The full range of wave periods and heights must be considered, due to the unpredictability of extreme tsunamis.

The ***effectiveness of coastal dunes*** to protect the hinterland from the impacts of tsunami also significantly varied from place to place. They proved efficient where the tsunami was less energetic and where the dunes were sufficiently high (no overwash!) and well vegetated. Whether this will also be true for larger periods (30-60min) and larger heights of the tsunami can only be answered by reliable modelling. Innovative solutions using geotextile or other materials to reinforce coastal dunes and to make them resilient for extreme tsunamis may also represents an important research issue.

Overall, it can be concluded that natural barriers have contributed differently to increase the resilience of coastal zones to tsunamis, but they were generally unable to ensure full protection of urbanized areas on their own.

The development of prediction models for the hydraulic performance of natural tsunami barriers and for their stability against extreme tsunamis still remains an urgent interdisciplinary research tasks, particularly involving researchers from geosciences and coastal hydrodynamics.

2.2.2 Man-made Tsunami Barriers

The damage reported from the 2004 tsunami is generally related to harbour structures, breakwaters and sea walls, but also to various types of buildings within the inundation reach of the tsunami.
The coastal structures were designed for the protection against storm waves. Most of them totally collapsed or were seriously damaged due to much higher:

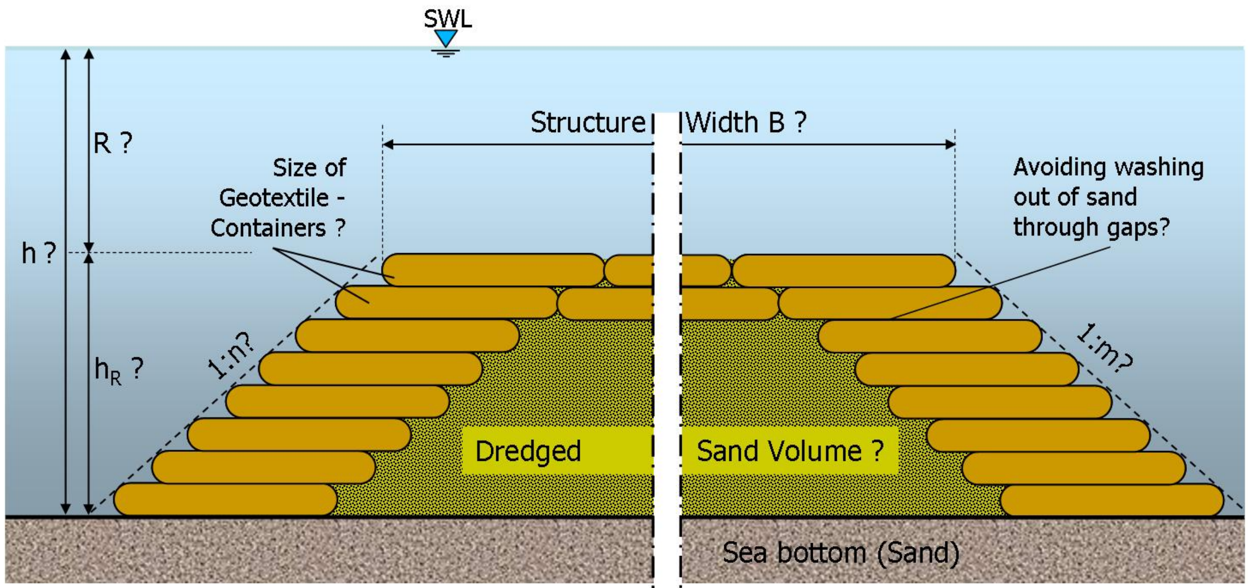
- ► impact forces leading to sliding, tilting or breakage of the structure members
- ► wave overtopping leading to erosion and undermining from the rear side
- ► drag forces directed land- and seaward
- ► scouring and undermining potential of both incident and receding flow induced by the tsunami.

The development of models for the prediction of extreme impact forces of the incident tsunami and extreme drag forces from both the incident and receding tsunami, including their erosion, destruction and transport potential still remains a hot research issue. The same applies for the prediction of tsunami overtopping, (including its destruction potential) and for the prediction of scour development. Considering the multi-defence line strategy exemplarily sketched in Fig. 6 and the fact that no guidelines yet exist for the design against tsunami of any of the man-made defence structures indicated in the figure, it is particularly important to focus future research on the feasibility of (i) artificial reef barriers, (ii) onshore soft tsunami attenuation barriers and (iii) onshore mobile defence systems, including the prediction of their hydraulic performance and structural integrity when subject to major tsunamis:

(a) Artificial Reef Barriers

The hydraulic performance of artificial reefs, including the underlying processes involved in the interaction with storm waves is well-understood. Analytical and numerical models also exist to predict wave transmission, reflection and energy dissipation for both simple reef structures (Bleck and Oumeraci, 2004) as well as for more sophisticated submerged wave absorbers (Oumeraci and Koether, 2004). However, there are significant differences between ***tsunami-reef interaction*** and ***storm wave-reef interaction*** resulting in different damping performances.

For tsunami, much larger dimensions of the reef barrier are expected in order to achieve any significant damping. Therefore, a low-cost structure made of dredged sand encapsulated by mega-geocontainers filled with sand may represent a possible alternative (Fig. 8).



Reef Parameters

- Location depth h
- Structure width B and slope steepness 1:n and 1:m
- Reef height h_R and submergence depth R
- Size (volume, weight) of geotextile containers

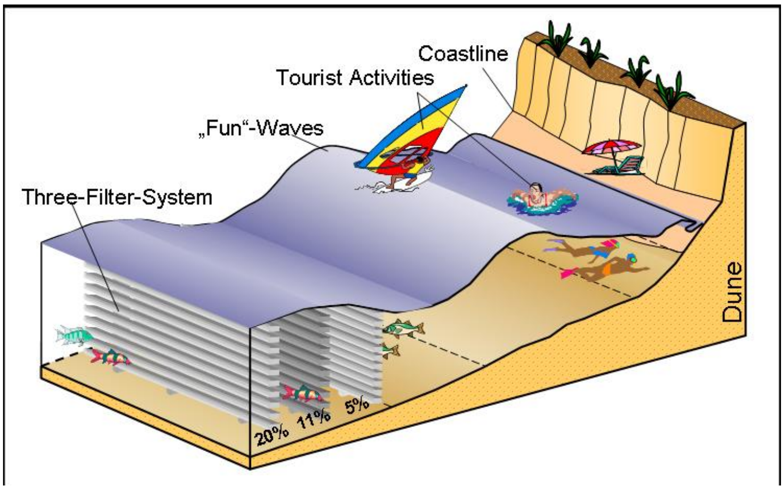
must be determined as a function of target incident Tsunami wave parameters and target transmitted wave parameters. The latter will depend on the nature of the next defence line(s) and the vulnerability of the flood prone area.

Fig. 8: Artificial Reef Made of Dredge Sand Protected by Mega-Geocontainers

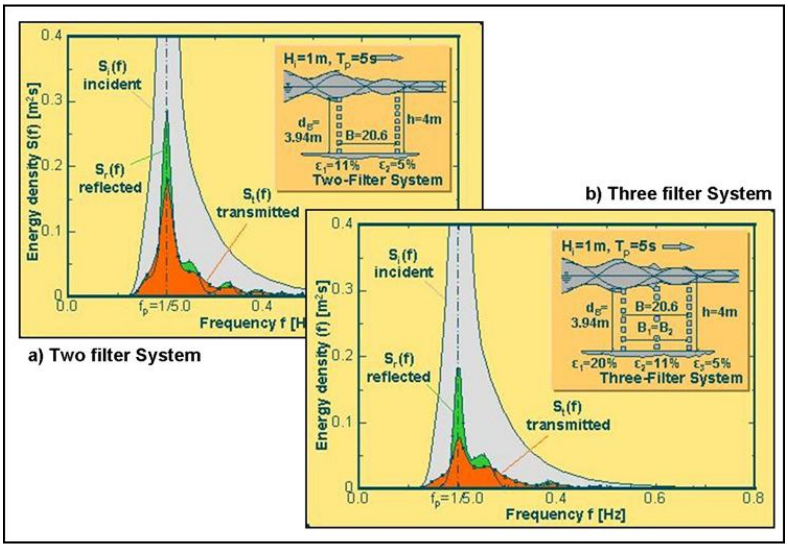
The development of a numerical model will allow to determine the required location depth and dimensions of the reef for a given range of tsunami periods and heights, and thus to assess the technical and economic feasibility.

Alternatively, a more sophisticated solution using a submerged wave absorber which proved efficient not only for storm wave trains (Fig. 9), but also for solitary waves.

Although the wave absorber shown in Fig. 10 was initially designed for storm waves only, large scale experiments have shown that a significant wave damping can also be achieved for solitary waves (Fig. 10). To predict the hydraulic performance and the wave loading which are required for both functional and structural design, a detailed flow model is needed.



a) Submerged Wave Absorber



b) Hydraulic Performance

Fig. 9: Submerged Wave Absorber for Coastal Protection Against Storm Waves (Oumeraci and Koether, 2004)

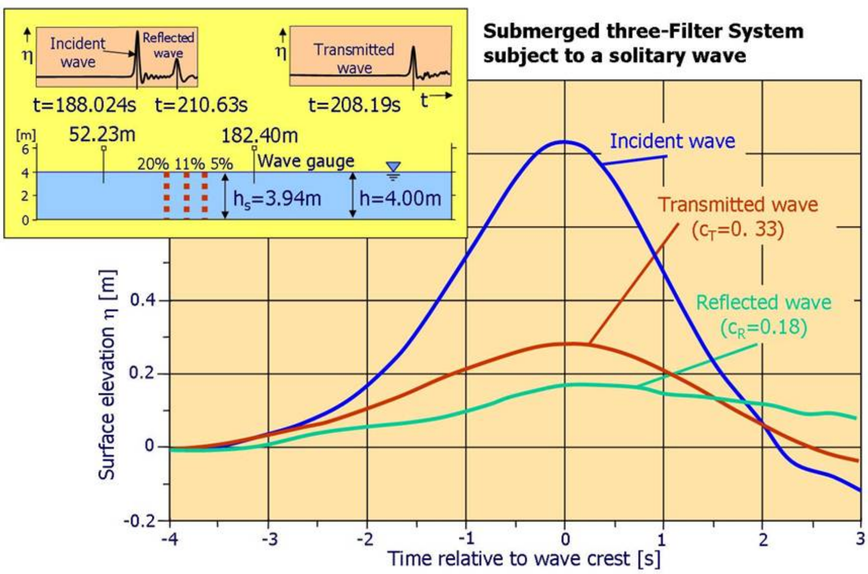


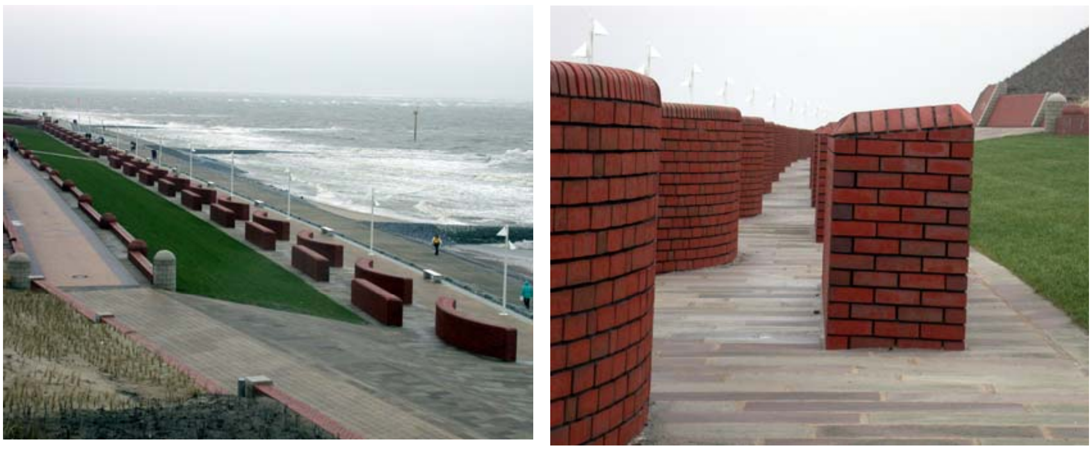
Fig. 10: Performance of Submerged Wave Absorber to Solitary Waves (Oumeraci, 2005)

(b) Onshore Soft Tsunami Attenuation Barriers

The still insurmountable difficulties associated with the prediction of the exceedance probability of a given extreme design tsunami as well as the field evidence experienced with seawalls and breakwaters during the 2004 Tsunami clearly suggest that protective structures should not be designed to completely stop the tsunami. In fact, this would be neither economically justifiable nor environmentally and socially acceptable. Moreover, the damages and losses which might result when the design conditions are exceeded may be in some circumstances even more enormous than a situation without any protection.

Therefore, softer protective structures aiming at progressively weakening the tsunami power without blocking completely the inundation and having the overall additional benefit of broadly blocking floating debris in a rather soft manner would be preferable. In this respect, dense and healthy coastal forests might represent an ideal natural barrier within the overall “divide-and-rule defence strategy” as sketched in Fig. 6.

However, coastal forests cannot be planted everywhere. due to climatic and geomorphological, socio-economic and other specific local conditions. In such cases, tsunami resistant man-made structures with a safe foundation (structural design) and a well-designed lay out to fulfill a similar attenuation function (functional design) may provide a soft alternative to beach forests. This is particularly suitable for urbanized and touristic coastal areas where the man-made protective structure should be aesthetically fitted into the local marine landscape. Such a concept (Fig. 11) has already been developed and investigated by the author, and successfully implemented to protect a touristic coastal stretch against storm waves of the North Sea (Norderney Island).



a) Overall view   b) Detail

Fig. 11: Sea walls for the Protection of Norderney Against Storm waves (Oumeraci, 2006)

(c) Tsunami Resistant Buildings for Vertical Evacuation

The tsunami loading of the various components of a typical multi-storey RC-building on columns (Fig. 6) which fulfills the seismic requirements and which can also be used for vertical evacuation in the case of a damaging tsunami is still unknown. A particular focus should be put on the following research issues:

- Hydrodynamic loading of the RC-columns during up-rush and down-rush of the tsunami. This should also include the impact loading of floating debris.
- Scouring around the building which is rather critical when the typical tsunami wave recedes
- Upward tsunami loading of the decks of the first and second storey
- Hydrodynamic loading of wall panels by the up- and down rushing tsunami.

For this purpose, systematic scale model testing in the laboratory will be required to understand the underlying processes associated with the tsunami-structure interaction and to generate reliable data for the validation of prediction models. The latter still need to be developed.

(d) Mobile Defence Systems for Critical Facilities

Field evidence of the 2004 Tsunami disaster has shown that tsunami inundation can propagate up to 6 km inland (In the tsunami following the eruption of Krakatoa even up to 8 km through the primary forest and about 1000 years ago in West Australia up to 30 km.). Although the propagating tsunami bore becomes surprisingly much slower inland, it may still significantly affect critical facilities such as power plants, water supplying facilities, chemical manufactures, etc. Therefore, an individual flood protection of such critical facilities through innovative movable defence structures would be required. Such structures should not only be affordable, but must also be easily, rapidly and safely raised when the warning is issued – even after many tsunami-free decades. When not in operation they may serve as walkways or other purposes.

One possible alternative has been developed and tested in the LWI-wave flume together with the Swiss company “KWS-Technologic System AG” which can be operated pneumatically, mechanically and hydraulically (Fig. 12).

Models to predict the hydraulic performance and the effects of similar structures far inland also need to be developed.

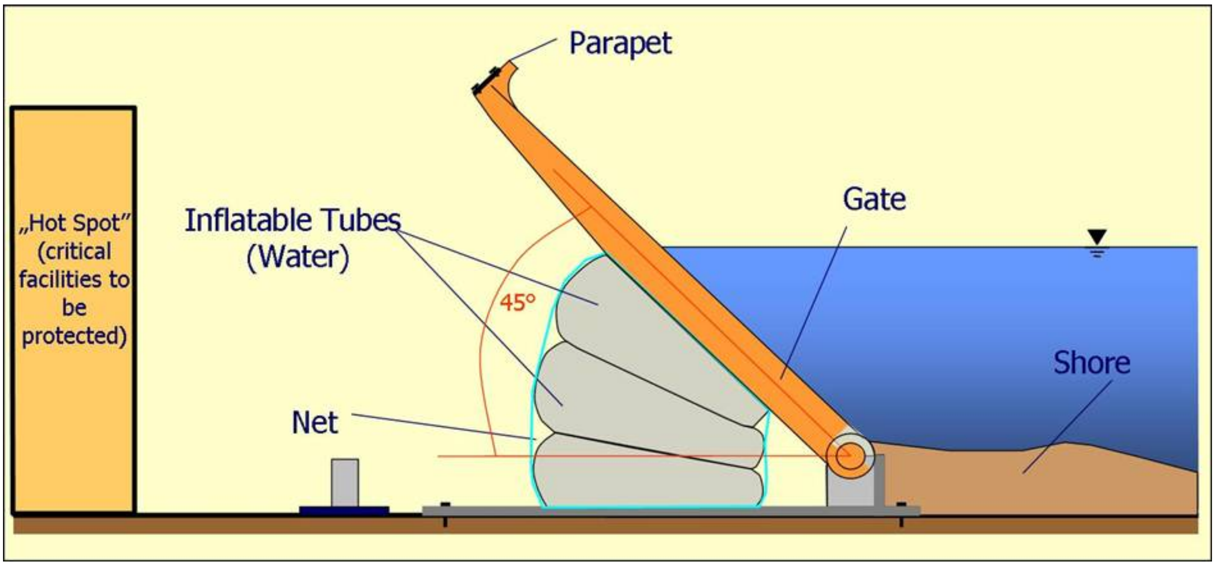


Fig. 12: Mobile Flood Defence System for Critical Facilities (patented)

The overall objective of future basic research related to the hydraulic performance and loading of natural barriers and man-made structures for the protection against tsunami is to generate the scientific knowledge and the prediction models which are required to elaborate design guidelines for a class of defence structures, including the assessment and management of flood risk when subject to major tsunamis.

3. Objectives and Prospective Outcomes

The objectives of the proposed "DFG-Round Table Discussion", which should particularly bring together researchers from geosciences and from coastal engineering, are threefold:

(a) Identify more precisely the aforementioned knowledge gaps and modelling weaknesses, including the implications for priority research needs.

(b) Briefly report on completed, ongoing and planned related projects, which might substantially contribute to close the aforementioned knowledge gaps and to improve present tsunami modelling. The reports should also take into account worldwide research activities from other research teams not present at the "DFG-Round Table Discussion".

(c) Derive from the results of items (a) and (b) the priority research topics for which (i) cross-fertilization between researchers in geosciences and coastal engineering sciences is urgently required and (ii) closer cooperation between German researchers (DFG-funding!) and US researchers (NSF-funding!) may substantially contribute to avoid duplication of research efforts and to save both financial resources and time.

The ultimate outcomes expected from the Round Table Discussion are among others:

- Definition of mechanisms and procedures for exchanging the results of completed and ongoing related research projects between German and US researchers
- Specification of "Individual Research Projects" (IRP) to be incorporated in the following tentative "**Joint Project Clusters" (JPC)**:

  ► **JPC1**: Nearshore effects on tsunami propagation and modelling, including the interaction with natural barriers (coral reefs, sand banks, etc.) and man-made structures (artificial reefs, breakwater, groins, etc.)
  ► **JPC2**: Onshore effects on tsunami propagation and modelling, including the interaction with natural barriers (beaches, dunes, forest vegetation, etc.) and man-made structures (sea walls, reinforced dunes, buildings and infrastructure)
  ► **JPC3**: Effects of debris on tsunami propagation and modelling, including the impact of debris flow on buildings, infrastructures, etc.

Moreover, a **JPC4** on "Tsunami Generation and Modelling" might also be considered, although it is not directly within the scope of the proposed theme of the "Round Table". This might be necessary, because

(i) the knowledge on tsunami source parameters is still too poor and the uncertainty bands of both seismic data and initial water wave characteristics are still too large, and
(ii) reliable near- and onshore tsunami modelling strongly depends on the accuracy of the model for tsunami generation and propagation in deeper water.

JPC4 is also important, because the impact of past tsunami can be used to determine the occurrence probability of major tsunami which is required in any functional and structural design as well as in any elaboration of probabilistic tsunami hazard maps. For this purpose, the use of historic and prehistoric tsunami deposits will be necessary. Moreover, the results of tsunami deposit studies together with "hydrodynamic and morphodynamic" calibration studies will also contribute to enhance near- and onshore tsunami modelling.

A further candidate topic for discussion at the "Round Table" is also the exploration of the elaboration and management of a **Joint Data Base** for model validation, including the agreement on standard procedures.

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