Office for the Coordination
of Humanitarian Affairs

K.
HAZARD IMPACT SUMMARIES

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Section contents

K. HAZARD IMPACT SUMMARIES

These hazard summaries offer a general overview of the potential impact of the most common natural hazards that UNDAC teams may be deployed to. They aim to assist in understanding the impact and priority needs in the immediate aftermath of a sudden-onset disaster caused by a natural hazard-related disaster in an affected society.

Furthermore, they aim to develop hazard-specific literacy among UNDAC members to better understand the challenges of operating in an area affected by natural hazard-related disasters and how they can impact the UNDAC mission.

The summaries are not meant to offer a detailed analysis of the specific impact of different hazards in various settings. It's important to thoroughly assess the context during deployment, as each disaster has its own unique characteristics, and contextual factors will greatly influence humanitarian needs and response. The summaries can, however, be used as a starting point after an alert of a hazard impact has been received to prepare for an emergency response and guide further information collection.

K.1 Earthquakes

An earthquake is a phenomenon that occurs when there is a sudden slip on a fault line, which results in ground shaking and radiated seismic energy. This can also be caused by volcanic or magmatic activity or other sudden stress changes in the earth. The duration of most earthquakes is usually a minute or less. However, aftershocks can occur on and off for a few days, weeks, or even months following the main earthquake, depending on its magnitude.
There are different ways to measure the magnitude of an earthquake. The Moment Magnitude Scale (Mw) is the most used as it is based on the seismic moment, which is related to the amount of total energy released by the earthquake. Similar to the Richter scale, an increase of one step on the logarithmic scale of moment magnitude corresponds to a 101.5 ≈ 32 times increase in the amount of energy released, and an increase of two steps corresponds to a 103 = 1000 times increase in energy. Consequently, an earthquake of 7.0 Mw contains 1000 times as much energy as a 5.0 Mw and about 32 times that of a 6.0 Mw.

Earthquakes with a magnitude of 7.0 or higher can cause intense shaking and other serious consequences over a wide area. Earthquakes with magnitudes between 6.0 and 6.9 may cause a lot of damage in very populated areas, while smaller earthquakes can still cause damage to weak structures near the epicentre.

There are qualitative intensity measures that describe the severity of an earthquake based on its effects on the earth's surface, infrastructure, and population. One such measure is the Modified Mercalli Intensity (MMI) scale. The MMI scale ranges from I (not felt) to XII (Total Damage). Structural damage typically begins at VI, but this can vary depending on the fragility of buildings in a given region.

Other measures to quantify ground shaking intensity include ground motion parameters such as peak ground acceleration (PGA), peak ground velocity (PGV), and elastic spectral acceleration for a given period of vibration (SA).

The basic rule is that earthquakes are unpredictable natural phenomena that cannot be forecasted in terms of location, magnitude, or time. Ground shaking from an earthquake is unique and can vary significantly from location to location. However, as many other natural hazards that are occurring around us, earthquakes obey simple laws of nature, that allow us to infer how these complex events may unfold.

Several properties of the earthquake rupture, such as rupture directivity or so-called 'super-shear' ruptures, may impact the strong ground motion generated. Theoretically, for two identical earthquakes that differ only in depth, the deeper earthquake would be expected to result in lesser intensity on the surface.

Earthquakes release the stress accumulated along fault lines, but not all the stress is released during a single large earthquake, and this 'left-over' stress is the origin of any sequence of aftershocks that follow the first EQ. When the size and position of the fault line that generated the main EQ is known, one can roughly 'predict' the area where the aftershocks will occur. However, in some cases, the main EQ may trigger another EQ of considerable magnitude because of the stress transfer, which may be outside this 'predicted' area. Again, the size, location and magnitude of such 'triggered' cannot be 'known'.

While there may be some exceptions, the temporal decay of the aftershock frequency can generally be characterized by Omori's law, which states that the rate of earthquakes triggered by a main shock decay with time according to an inverse power 1/tp of time with an exponent p≈1. This mathematical model explains how the number of aftershocks is very high during the first days following the earthquake and decreases following a predictable pattern. Conclusively, the first hours and days following an earthquake will have the highest risk of new and strong earthquakes, referred to as aftershocks. The magnitude and frequency of these aftershocks will follow the same trend, making it possible to "predict" the number of earthquakes with the same magnitude following a main shock. For example, if the main shock was M6 you can expect to have 10 M5s, 100 M4s, etc.

These considerations have almost universal validity and do not depend on geological or tectonic settings. There is, however, a caveat one should be acutely aware of. When applied to a sequence of seismic events these laws are strongly linked to the fault rupture mechanism. In other words, they are valid only if we have a single rupture along a single fault, i.e., only one major seismic event along the considered fault line. Whenever there is a new rupture in the fault line, like a major aftershock, the considerations described above are reset and new calculations must be made.

K.1.1 Early warning

It is currently not possible to predict earthquakes or provide early warnings which could greatly reduce the risk of loss of life. However, some early warning systems and signs can provide a few seconds of notice before the earthquake shaking waves arrive:

- **Earthquake Early Warning Systems –** These systems rely on a network of seismic sensors that can detect the initial pulses of energy when an earthquake begins. The data is then analysed in real-time to predict the **expected** intensity of shaking and alerts are sent to surrounding areas, providing up to several seconds of warning. It is important to note that these alerts may not always target the public directly but instead focus on the automatic shutdown of critical infrastructures, such as natural gas distribution pipelines, etc.
- **Tsunami warnings –** Earthquake parameters (location, depth, magnitude) detected through seismic networks would assist Tsunami Early warning Centres to determine the tsunamigenic potential of the earthquake. Warnings are pushed out to threatened coastal areas, sometimes providing hours of lead time to evacuate. For earthquakes in close proximity to coastal areas, such warnings may not be possible, but the occurrence of a strong or long earthquake should be interpreted as a natural sign of self-evacuation. (See also **Section K.2** for more on tsunamis.)
- **Earthquake forecasting –** Long-term earthquake hazard assessments using historical data, and short-term aftershock forecasts, using the pattern known as exponential decay described above can indicate increased risk.

K.1.2 Rapid impact estimations

GDACS rapid impact estimation: Within [illegible] 30min from the main event there is an automatic definition of alert level for humanitarian activation, this includes:

- Areas that are mostly affected,
- Event map,
- Shakemap,
- Meteorological forecast map,
- Exposure estimate (affected area - intensity polygons, intensity affected places),
- Exposed population,

- Critical infrastructures,
- Estimated casualties.

Within the Global Disaster Alert and Coordination System (GDACS), under the Satellite Mapping Coordination Systems (SMCS), satellite mapping information products also become available when the relative mapping services are activated.

K.1.3 Physical impact

- Geological hazards like earthquakes do not occur as frequently as climate-related disasters. However, earthquakes have killed more people than any other type of natural hazard in the past twenty years.
- The impact of a shallow earthquake is typically characterised by surface fault rupture (and fissures), as well as subsidence or uplift. The strength and duration of ground shaking at any given location depends on several factors, such as the magnitude of the earthquake, the distance to the earthquake's epicentre, and the local soil conditions.
- Some types of terrain transmit seismic waves more easily than others. Buildings constructed on solid bedrock in compliance with the applicable seismic design codes are less likely to suffer damage, while those built on unconsolidated rock and sediments may experience greater amplitude and duration of seismic waves, thereby increasing the potential for damage.
- When saturated, certain terrain types, such as sandy sediments, can liquefy, meaning that the soil can behave like a liquid, causing both infrastructural damage and sinking of structures.
- The impact of an earthquake is mainly determined by two factors: the intensity of ground shaking caused by the quake, and the quality of structural engineering in the region, e.g., building codes, inspection before, during and after construction. Soil conditions, the level of preparedness of emergency services, and the resilience of the local population are also factors contributing to the level of impact.
- The degree of damage to buildings depends on various factors such as the horizontal and vertical irregularities of the building, the type and frequency of the waves the shake creates, the soil conditions, and the resilience of the building. Buildings that are only slightly or moderately damaged may collapse during large aftershocks.
- Earthquakes can cause considerable damage to infrastructure, e.g., power cables, telecommunications systems, water and sanitation pipes, and gas lines can be ruptured, severed, or extensively damaged, hampering relief efforts and day-to-day living.
- Damage to infrastructure following an earthquake can result in the release of flammable liquids or gases. This increases the risk of fires when they come into contact with ignition sources. Additionally, heating and cooking appliances may be overturned, which can also trigger destructive fires during and after the earthquake.
- Dams, embankments, and levees may fail during an earthquake, causing downstream flooding due to cracks and instability.
- Shaking caused by large-magnitude events can result in destabilization of slopes, leading to landslides and debris flows, particularly in mountainous regions. In addition, destruction of roads, bridges, and other infrastructure can make access and communication difficult. Landslides and debris can block roads or cause surface damage.
- Earthquakes that occur near coasts or oceans can cause tsunamis, which can be extremely destructive and increase the overall impact of the disaster. Locations situated at sea level are particularly vulnerable to such events. Furthermore, critical infrastructure such as ports and airports may become unusable due to the severity of the earthquake and/or tsunami.
- Tsunami-like seiche waves can impact areas close to large bodies of water. Earthquakes can change the course of rivers and result in flash floods. For more information on tsunamis generated by earthquakes, refer to **Section K.2.**

K.1.4 Direct impact on the population

- The leading cause of death after an earthquake is trauma resulting from building collapse or other seismic activity, accounting for up to 75-80% of fatalities.
- Death is rare for people who are outside a building at the time of the earthquake.

- Diseases and mortality rates in the weeks following an earthquake depend largely on the occurrence of epidemics. Outbreaks of diseases, however, are unlikely and usually of very modest proportions.
- Structural collapses from earthquakes generate trapped victims who may survive for several days. Under special, ideal conditions with food, water and temperate climatic conditions, survival may extend considerably. However, 85-95% of persons rescued alive from collapsed buildings are rescued in the first 24-48 hours after an earthquake.
- After an earthquake, the majority of injuries are minor cuts and bruises, followed by a smaller group with simple bone fractures, and a minority with multiple severe fractures and internal injuries, requiring surgery and intensive treatment for crush syndrome. Within the first three to five days, most injured individuals will arrive at medical facilities. There may be two waves of patients. The first wave will consist of casualties from the immediate surrounding area of the medical facility, followed by a second wave of referred cases from more distant areas as relief efforts are organised. Victims of secondary hazards, such as aftershocks and fires, may arrive at a later stage.
- Earthquakes can have long-lasting effects on mental health, particularly among children and teenagers. One of the most common mental disorders that can result from earthquakes is Post-Traumatic Stress Disorder (PTSD). PTSD is characterized by persistent, intrusive memories of the traumatic event, hyperarousal, avoidance of trauma-related cues, and negative changes in thinking and mood.
- Households begin their recovery efforts immediately after the earthquake. Major population movements are rare; however, it may occur in heavily damaged urban areas.

K.1.5 Aggravating factors

- In most cases, the closer an area is to the earthquake epicentre, the more intense the shaking will be, which in turn increases the likelihood of severe damage. The area closest to the epicentre is generally the hardest hit.
- Earthquakes closer to the surface cause more widespread damage due to the shaking spreading over a larger area.
- The time of day can have a significant impact on the severity of an earthquake, as it governs the number of people in large buildings, attending work or school, etc. Earthquakes occurring during nighttime hours can result in higher death tolls because more people may be asleep inside vulnerable buildings that may collapse. Additionally, emergency response efforts may be hindered by the challenges of mobilising resources during overnight hours.
- During an earthquake, poorly designed, inspected and constructed buildings and structures are more likely to fail and collapse, exacerbating the impacts. Unreinforced masonry buildings pose the greatest danger during strong earthquakes, with weaker masonry resulting in higher death tolls.
- Regions with fragile buildings, high-density populations, or local soil conditions that promote ground shaking may experience more severe and widespread damage from earthquakes of a given magnitude and other characteristics.
- Areas with higher population densities are at a greater risk of extensive damage and loss of life in the event of an earthquake, as more people and infrastructure are exposed.
- Populations that lack earthquake awareness training and warning systems are more vulnerable to adverse impacts as they may resort to behaviours that put them at greater risk. For example, going close to a shoreline not knowing of the tsunami risk, or taking cover close to structures rather than away from them, etc.
- Fire is a secondary effect of earthquakes that often causes damage. Because power lines may be knocked down and natural gas lines may rupture during an earthquake, fires are often triggered. Fire damages may be compounded if water lines are also broken during the earthquake, as there will not be enough water to extinguish the fires once they have started.
- In the event of an earthquake during winter in cold climates, survivors are at high risk of experiencing hypothermia, frostbite, and other illnesses caused by prolonged exposure to the damp and cold weather. Additionally, bad weather can

hinder rescue efforts and make response much harder. Furthermore, during the cold weather, there is a higher likelihood that stoves and fires are burning inside the houses that have collapsed, which significantly increases the chances of fires after the earthquake.

- When earthquakes occur in hot climates, the lack of water makes it harder for people trapped in rubble to survive.
- Hospitals could face power outages that could lead to the death of patients in intensive care units. Hospital personal may abandon their duty post in desperate need to reach out to their relatives.

K.1.6 Typical needs

Mobilizing an effective response after a major earthquake requires coordination across government agencies, disaster relief organizations, businesses, community groups, and civil society organisations.

- **Search and rescue -** Specialized INSARAG-certified urban search and rescue (USAR) teams are crucial for detecting survivors trapped in collapsed buildings and structures. Some of the first responders deployed are USAR teams tasked with locating and extracting survivors trapped under collapsed structures. Speed is critical for saving lives so these teams are deployed as quickly as possible to the most affected areas.
- **Medical care –** Local medical facilities are often overwhelmed by injured individuals, and, temporary field hospitals equipped with emergency medical personnel, supplies, and equipment are essential for treating those in need.
- **Logistics –** A combination of increased air traffic, congested air space and reduced airport capacities in the affected area will cause delays affecting all forms of relief transported by air. In-country air traffic will be similarly affected as international. Overland transport may be affected by increased population movements, damaged roads/train lines, and reduced capacity should be expected. Supply chains will also be disrupted. Destruction or damage to ports, bridges, and roads increases transportation costs and substantial shipment delays. With disruption to roads, rail lines, airports, etc., temporary solutions help ferry in aid and allow people to leave impacted zones.
- **Shelter –** When homes are destroyed, many people become homeless and require emergency shelter and housing solutions. The risk from aftershocks often leads to people settling outside their former homes, not wanting to move back in until the number of aftershocks decreases, and the building has been assessed by structural engineers. Resources to assist displaced persons are crucial in the aftermath. Immediate needs are shelter supplies such as tents, cots, blankets and essential living items like food, water and hygiene items. The opening of evacuation shelters equipped with temporary housing, food/water, hygiene services, medical aid, etc., should be prioritised.
- **Food/Water—** Disrupted infrastructure may cut off access to food and clean water. Distributing food rations, bottled water, and purification equipment helps stabilize supplies. Market support and cash incentives should be considered.
- **Sanitation –** Water supply, treatment and reconstruction of water supply systems and drainage/sewer systems is vital. Without proper sanitation and waste management, the situation for survivors will deteriorate rapidly and increase the risk of communicable diseases. Distribution of hygiene items, latrines and hygiene promotion should be prioritised.
- **Power supply –** Electrical infrastructure can be severely damaged. Bringing in generators, repair crews, and equipment, and coordinating repairs is key to restoring power access.
- **Communication networks –** Damaged communications systems isolate people and prevent coordination. Rapid deployment of temporary cell towers, satellite phones, radios, and internet connectivity aids rescue coordination, supports situational awareness and reconnects affected population.
- **Debris removal –** Rubble can block roads and prevent access. Heavy construction equipment, including bulldozers, excavators, cranes, and crews, are indispensable assets for clearing roadways, providing access to blocked areas, and enabling search and rescue efforts. Finding areas to dispose of rubble can be a challenge, however, and debris should be recycled as far

as possible. It is also important to be aware of hazardous materials, like asbestos, that may be part of the rubble and ensure this is removed in a safe manner.

- **Protection –** Emergency situations also tend to exacerbate existing inequalities among the population and lead to a rise in human rights and protection concerns. Special considerations should be given to known protection risks in the context. See also **Chapter G.2** Centrality of protection and quality response. A breakdown of social structures and services can result in increased risks of exploitation, abuse, and neglect for vulnerable groups, and relief efforts must prioritize the unique needs of these groups to ensure their safety and well-being.
- Women and children often face heightened vulnerability and are disproportionately affected. Female-led households may have less access to resources, financial independence, and decision-making power, which complicates their ability to recover. Children are particularly susceptible to physical harm and psychological trauma. They may be orphaned, and displacement often disrupts their education and routine, leading to long-term challenges.
- **Environmental—**Technological accidents can be triggered by earthquakes, which can damage hazardous installations and release hazardous substances, leading to fires or explosions, gas leaks, damaged facilities, chemical spills, etc.

K.1.7 UNDAC mission

- Mobilisation and deployment happen within hours of the event. Selected team members must be fully self-sufficient with food/water for 72 hours, a tent, a sleeping bag, a field mattress, and hygiene articles. Check climate and weather when packing and be prepared to work and sleep in tented conditions for weeks.
- Expect congested air traffic and severe delays. Travelling with an international USAR team or another relief flight is preferable. The risk of delayed luggage is also higher, so make sure to pack essentials in carry-on luggage.
- On arrival, ensure a Reception & Departure Centre (RDC) for international relief teams has been established and be prepared to stay behind at the airport to support it. Liaise with National Emergency Management representatives already at the airport if they're there or immediately afterwards. Alert the RC/HC of your arrival in parallel. It is UNDAC's role to support on-site coordination of international USAR operations and the UNDAC team and the UCC should establish liaison and coordinate with each other as soon as possible in the mission. A dedicated UNDAC USAR Liaison Officer (LO) should be appointed as soon as possible and ensur that the USAR operations is linked with the overall humanitarian operation. See also **Chapter D.5** on the Reception & Departure Centre and **Chapter G.10.1.5** for more on UNDAC USAR Liaison.
- Normal hygiene services will be disrupted or non-functional. Make sure to bring sanitary items and other articles for washing and staying clean, such as wet wipes, toilet paper, and sufficient clothing. Take care of any bruises, small wounds, or injuries immediately to prevent infection.
- Access to food and water in the disaster area may be disrupted. Consider acquiring field rations from USAR teams.

K.1.8 Safety concerns

All earthquakes happen in sequences. Be aware that some earthquakes are actually foreshocks, and a larger earthquake might still occur. Leftover stress will remain in the fault lines where the original earthquake happened, and this stress will be released as aftershocks or new earthquakes of various magnitudes and depths throughout the mission. Aftershocks pose a significant risk, causing further damage and increasing stress for both victims and aid workers.

Consider staying outside and a safe distance from infrastructure throughout the mission.

Specific safety considerations:

- **Building collapse—**Buildings and other structures damaged by shaking can become more unstable and collapse after the initial earthquake, putting anyone inside or nearby in danger. Even a small aftershock can lead to the collapse of a building if it has already been damaged. Several damages may not be visible to the naked eye, and therefore, it is important to thoroughly inspect any structure that has been impacted by an earthquake.

- No infrastructure can be assumed safe without proper assessment by subject matter experts, such as certified structural engineers. These professionals are the only ones who can provide advice on the extent to which infrastructure has been compromised, and they should check both workplaces and resting places. Incoming USAR teams may have the capacity to carry out such assessments. Should a building be cleared as a work or rest space, make sure to establish escape routes and be prepared to evacuate at short notice. As general guidance:
  - If caught in an aftershock, drop to the floor, take cover and hold on.
  - Identify safe places in buildings, such as under sturdy tables or desks or against interior walls away from windows, bookcases, or tall furniture that could fall on you.
  - Keep a flashlight, a pair of shoes, appropriate clothing that can be put on fast, a grab bag with essential items packed, and your personal identification documents near your resting place in case you need to evacuate at night. You may also want to consider sleeping with most of your clothes on to avoid spending time dressing.
  - In a high-rise building, avoid using the elevators and stay away from windows and outside walls.
  - Wear a whistle to attract attention to yourself and a facemask to protect yourself from dust.
- **Power lines –** Shorted lines, damaged poles, and wires heighten the risk of electrocution and fires. Stay clear of any sparking or downed cables.
- **Gas leaks and fires –** Ruptured gas pipes lead to leaks, which increase the chance of fire or explosions. Evacuate areas where you smell or hear gas leaks. Gas leaks, electrical shorts and toppled heat sources heighten fire risk. Have extinguishers ready and avoid sources of sparks while evacuating.
- **Landslides/mudslides –** Earthquakes can destabilize slopes and loosen debris. Watch for falling rocks, debris flows, and mudslides - especially near mountains/hills after heavy rains.
- Dam failures – Damage can cause dams to fail without warning, rapidly flooding downstream areas. Stay away from dams and low-lying areas.
- **Sanitation –** Compromised water and sanitation infrastructure can lead to sickness from poor hygiene. Store clean water safely and apply good hygiene practices to prevent contamination.
- **Chemical releases–** Failure to contain toxic chemicals may occur even in small premises, like shops, etc. Do not enter unless the space has been declared a safe atmosphere.

K.1.9 Security concerns

Chaos and confusion can lead to potential security risks. These can include increased crime rates due to overwhelmed law enforcement and a temporary breakdown of law and order. The risk of regular crime and petty theft may rise as people who have been severely affected by the event may resort to negative coping mechanisms. Both workplace and rest-place need to be established with sufficient security measures in place.

K.2 Tsunamis

A tsunami is a series of ocean waves caused by earthquakes or other phenomena such as volcanic eruptions, underwater landslides, coastal rock falls, and meteorite impacts, leading to significant water displacement in the ocean. It is a complex event that can last for many hours before the situation returns to normal. A tsunami consists of multiple waves in succession, and the first to arrive on the coast is not always the largest or most destructive.

Out of all the listed phenomena, earthquakes are the primary cause of tsunamis, accounting for 80% of occurrences. Particularly, when earthquakes occur in the regions where tectonic plates converge, and one plate subducts beneath another, the resulting tsunamis can be exceptionally catastrophic in their size and impact.

Tsunami waves have the potential to grow to enormous dimensions and can travel across entire ocean basins with very little energy loss. They are much faster than any wave produced by the wind in the open sea and can reach speeds of 700-800 km/hour in deep ocean.

Tsunami waves in the open sea are hardly noticeable due to their low height, typically ranging from a few centimetres to a few dozen centimetres. For example, a ship sailing on the open sea can be hit by a tsunami without passengers noticing anything unusual. However, as the wave approaches the coast, it transforms and becomes shorter in length but taller in height. Its speed decreases proportionally with the depth of the water, and as a result, the height of the wave increases, creating wavefronts that can reach up to several meters. When the tsunami reaches the coast, its speed reduces compared to the open sea, but it can still reach a speed of typically 25 km/hour.

Tsunami waves are distinct from waves generated by wind or weather disturbances, which only affect the surface of the water, because the movement of tsunami waves affects the entire water column from the bottom of the ocean to the sea surface. After the initial rise, the force of gravity makes the water mass move horizontally, generating tsunami waves that propagate outward in all directions similar to ripples from a rock thrown into the water. They can travel for thousands of kilometres without losing energy, allowing them to strike with great force on coasts far from their origin. The force of a tsunami wave, even if it is just 20-40 centimetres high, is powerful enough to knock down an adult man and drag him into the sea, or to move a heavy car for tens of meters. They can advance a few of kilometres inland, destroying everything in their path and causing significant damage.

The first sign of a tsunami wave is often a significant rise or fall in sea level along the coast, that usually depends on the orientation of the fault that generated the earthquake in relation to the coast. The change in sea level can sometimes be noticed as a ‘negative wave’ where the water pulls back unusually far from the shore, exposing the seabed for several hundred meters that is normally underwater. Conversely, it may appear as a fast-rising tide or as a series of growing waves or as an actual wall of water causing the water level to rise by several metres and unexpected inundation of the coastline, flooding areas that are typically dry.

K.2.1 Early warning

The UNESCO Intergovernmental Oceanographic Commission (IOC-UNESCO) coordinates the global implementation of tsunami warning systems and supports the IOC Member States in assessing the tsunami risk and in educating communities at risk about resilience measures. Four Intergovernmental Coordination Groups (ICGs), corresponding to the regions Pacific (ICG/PTWS), Caribbean (ICG/CARIBE-EWS), Indian Ocean (ICG/IOTWMS), and Mediterranean, Northeast Atlantic and its Connected Seas (ICG/NEAMTWS), have been established to address regional needs. Additionally, each ICG counts on the strategic advisory of specialized Working Groups whose members are professionals from key disaster management and research institutions. In case of an earthquake or volcanic event with the potential of generating a tsunami, the designated Tsunami Service Providers (TSPs) of each ICGs officially provide timely tsunami information products to the designated Tsunami Warning Focal Points / National Tsunami Warning Centres (TWFP/NTWC) of Member States. It is then the responsibility of mandated national organisations operating within the legal framework of the sovereign nation in which they reside and serve, to provide alerts to their citizens and communities.
There are currently 12 accredited Tsunami Service Providers (TSPs) that monitor seismic and sea level activity and issue timely tsunami threat information within the IOC-UNESCO framework to NTWCs / TWFPs and other TSPs operating within an ocean basin.

Seismic networks can provide information on earthquake parameters such as location, depth, and magnitude. Tsunami Early Warning Centres can utilize this information to determine the potential for the earthquake to generate a tsunami. Coastal areas at risk of tsunamis are alerted through warnings that provide a lead time of several minutes to hours, allowing people to evacuate to safety.

It might not be possible to issue tsunami warnings with sufficient lead time, especially for those coastal regions that are very close to the tsunami source zones. For example, an earthquake in a small water basin like the Mediterranean can result in a tsunami hitting the shore just a few minutes later. In such cases, if a strong or long earthquake is felt, it should be interpreted as a natural sign to evacuate oneself immediately.

K.2.2 Rapid impact estimations

GDACS rapid impact estimation: Within [illegible] 30min from the main event there is an automatic definition of alert level for humanitarian activation, this includes:

- Areas that are mostly affected,
- Event map,
- Tsunami travel time map,
- Simulated maximum coastal wave height (geo-referenced tiff files),
- Meteorological forecast map,
- Exposure estimates of tsunami-affected locations with expected/measured wave height and time of arrival,
- Exposed population,
- Critical infrastructures.

Within GDACS, under the Satellite Mapping Coordination Systems (SMCS), satellite mapping information products also become available when the relative mapping services are activated.

However, authoritative information comes solely from designated National Tsunami Warning Centres (NTWC) or Civil Defence, Civil Protection or any other designated National Emergency Management authority.

K.2.3 Physical impact

- Damage and destruction from tsunamis is the direct result of the following factors:
  - » Inundation
  - » Wave impact on structures
  - » Erosion
  - » Strong currents
  - » Debris
- Strong tsunami currents can erode foundations, causing bridges, seawalls and embankments to collapse. The forces from a tsunami may destroy the framework of buildings and other structures and drag forces can move houses and overturn heavy objects like railroad cars. Floating debris, including boats, cars, and trees, can also cause considerable damage. These debris particles can become dangerous projectiles that may crash into buildings, piers, and other vehicles.
- Ships and port facilities can be damaged by surge action caused by even weak tsunamis.
- Fires resulting from oil spills or combustion from damaged ships in port, or from ruptured coastal oil storage and refinery facilities, can cause huge damage.
- In the aftermath of a tsunami, power shortages may last for weeks in the affected areas.
- Sewage and chemical pollution following destruction can result in secondary impacts. Damage to intake, discharge, and storage facilities can also present dangers.
- Tsunamis not only cause immediate damage due to the kinetic energy carried by moving water but can also have long-term effects on the environment, agriculture, and fisheries. When a tsunami hits, a considerable amount of saltwater gets deposited on the ground, which accumulates and concentrates salt. This salt buildup can kill off existing plants and trees and prevent new ones from growing, making cultivation nearly impossible. This can disrupt the livelihoods of people who depend on agriculture, exacerbating the damage caused by the waves.
- While they can absorb some of the tsunami energy, sediment and coral rubble thrown about by a tsunami can damage coral reefs. Vast destruction of coral reefs, mainly due to geo-morphological changes resulting in the uplifting or submergence of reefs, has been observed in tsunamis.
- Damage to mangroves can be highly variable, ranging from little damage in some areas to the destruction of entire forests in other areas.
- Areas lying immediately outside the area affected by the wave may appear untouched, as if there were a clear delineation between affected and unaffected areas.

K.2.4 Direct impact on the population

- When tsunamis hit low and densely populated coastal areas, they can cause human and economic losses that far outnumber other natural disasters.

- People caught in tsunami waves often drown or experience physical trauma due to debris and turbulent waves. Women are often more exposed, as they have the care of small children and are slower to evacuate. Evidence suggests that the fatality rate for persons with disabilities can be up to four times higher than that of the general population.
- Injuries are similar to those of earthquakes (see **Section K.1.4**).

K.2.5 Aggravating factors

- When an earthquake that triggers a tsunami occurs near land, the resulting impact can be compounded by typical earthquake damages (see **Section K.1.3** and K.1.4).
- Coastal areas that are heavily developed with a tourist industry, port facilities, etc., are at higher risk of huge tsunami impacts.
- A lack of tsunami preparedness, such as levees, evacuation procedures, escape routes to higher land, etc., can have a devastating effect on people and infrastructure.
- Damaged critical infrastructures, such as dams, power plants, ports, airports, etc., that become inundated, or experience structural damage can disrupt services. Coastal protection structures such as sea walls may also be damaged, leaving the coastal population exposed to future hazards.

K.2.6 Typical needs

- As with earthquakes, mobilizing an effective response after a tsunami requires a concerted effort across government agencies, disaster relief organizations, businesses, and community groups.
- There will be a need for assistance with:
  - » Emergency medical care.
  - » Provision of shelter solutions for displaced people, including services for water, sanitation, and safe spaces.
  - » Food and water.
  - » Restoration of power supply and communication networks
  - » Protection services for the most vulnerable segments of the population
  - » Debris removal.

Seawater may flood sewage systems, resulting in an overflow of wastewater that may contaminate drinking water sources and increase the risk of water-borne and communicable diseases.

Stagnant water left over from the wave may become breeding spaces for insects and increase the risk of vector-borne diseases.

Increased air traffic, congested airspace, and reduced airport capacities may delay the delivery of relief supplies by air. Factors such as increased population movements, damaged roads or train lines, and reduced capacity may also impact inland transportation.

When a tsunami is combined with earthquake impacts, USAR and restoration of logistics services over a larger area may be needed.

Emergency situations also tend to exacerbate existing inequalities among the population and lead to a rise in human rights and protection concerns. Special considerations should be given to known protection risks in the context. See also Chapter G.2 Centrality of protection and quality response.

A breakdown of social structures and services can result in increased risks of exploitation, abuse, and neglect for vulnerable groups, and relief efforts must prioritize the unique needs of these groups to ensure their safety and well-being.

Women and children often face heightened vulnerability and are disproportionately affected. Female-led households may have less access to resources, financial independence, and decision-making power, which complicates their ability to recover. Children are particularly susceptible to physical harm and psychological trauma. They may be orphaned, and displacement often disrupts their education and routine, leading to long-term challenges.

Informal settlers in coastal areas are also more vulnerable as housing is poor and after a tsunami their lack of land rights are exposed.

K.2.7 UNDAC mission

Given that a tsunami most often is an effect of an earthquake, and an impacted area may be affected by both hazards, UNDAC's mobilization and mission will be similar in nature, with the same needs for rapid deployment and self-sufficiency.

When the tsunami-affected area is far from the triggering earthquake, and the risk of after-shocks is low, it may be possible to establish work and rest places in buildings immediately outside the areas affected by the wave. Seismologists and Tsunami Early Waring Centres should be consulted for this however.

K.2.8 Safety concerns

In addition to normal safety concerns associated with earthquakes, be aware of the increased risk of water-borne, vector-borne, and communicable diseases. Pay particular attention to good hygiene practices and the use of mosquito nets and repellents.

K.2.9 Security concerns

Similar to earthquakes (see **Section K.1.9**), but less impactful if the affected area is smaller and normality exists outside the area.

K.3 Tropical cyclones

Tropical cyclones (TC) are one of the biggest threats to life and property even in the formative stages of their development. They generate several different hazards that can individually have significant impacts on life and property, such as storm surge, flooding, extreme winds, tornadoes, and lightning. Combined, these hazards interact with one another and substantially increase the potential for loss of life and material damage. In fifty years, from 1970–2019[1], tropical cyclones led to a daily average of 43 deaths and US$ 78 million in losses.

Tropical cyclones are rapidly rotating storms that begin over tropical oceans. They can vary in size (from 200 to 800 km) and intensity (related to the maximum wind speed). Tropical cyclones are also called hurricanes in the Atlantic and Caribbean, and typhoons in the North West Pacific.

Tropical cyclones are classified according to their maximum sustained wind speed and location (see TC classifications in the table below and more on the WMO website). This classification does not consider the tropical cyclone's size nor the associated hazards such as storm surges or rainfall.

See https://www.nhc.noaa.gov/aboutsshws.php for a visualisation of the impact on houses and vegetation at various wind speeds. A detailed description of the impact on buildings, roads and other infrastructure can be found at Microsoft Word - SSHWS-table-final.docx (noaa.gov).

Approximately 85 tropical storms develop annually. More than half (45) of these storms intensify into tropical cyclones, known regionally as hurricanes or typhoons. In the northern hemisphere, the peak of the season is from August to October. In the southern hemisphere, it is from January to March. In the North Indian Ocean, it is associated with the movement of the monsoon, and the peak of cyclonic activity is around May and November.

More information can be found at https://wmo.int/content/tropical-cyclone-climatology and in the World Meteorological Organization (WMO) Coordination Mechanism (WCM) hazard calendar for tropical cyclones available at https://community.wmo.int/en/wcm-hazard-calendars.

TCs are multi-hazard events by essence. They can bring together several dangers, including destructive winds, storm surges, high waves, heavy rainfall, and tornadoes. These lead to secondary hazards like mud/landslides and flooding. This combination of hazards makes them particularly dangerous and challenging to manage. For example, the

1 World Meteorological Organization (WMO) Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019)

combination of heavy rain and storm surge leads to coastal inundation/flooding (https://www.nhc.noaa.gov/surge/surge_intro.pdf). Coastal communities especially need to be well-prepared and have robust emergency plans in place to mitigate the impacts of these events.

The longer the tropical cyclone circulation system is sustained after landfall, the more likely that torrential rains will be maintained.

K.3.1 Situational awareness and anticipatory action

Tropical cyclones are monitored from their early stages through international cooperation and coordination. WMO coordinates activities through its Tropical Cyclone Programme. Regional Specialized Meteorological Centres (RSMCs) and Tropical Cyclone Warning Centres (TCWCs, https://community.wmo.int/en/tropical-cyclone-regional-bodies) detect, monitor, analyse, and forecast tropical cyclones' intensity, their track and related hazards in their area of responsibility. Those centres provide real-time advisory information to National Meteorological and Hydrological Services (NMHSs) which issue the official warnings (see https://worldweather.wmo.int/en/home.html and https://severeweather.wmo.int/).

Tropical cyclones may be difficult to predict because they can suddenly weaken or change their track. Meteorologists adapt computer modelling to

Table 1 Classification of tropical cyclones (see also https://wmo.int/content/classification-of-tropical-cyclones).

Average wind speed (km/h)	North Atlantic, East & Central North Pacific	North Indian: Arabian Sea & Bay of Bengal	North West Pacific	South West Indian	South East Indian/ South Pacific
< 63	Tropical Depression				
63-117	Tropical Storm	Cyclonic Storm & Severe Cyclonic Storm	Tropical Storm & Severe Tropical Storm	Moderate & Severe Tropical Storm	Tropical Cyclone Category 1 & 2
≥ 118	Hurricane Category 1	Very Severe Cyclonic Storm	Typhoon	Tropical Cyclone	Severe Tropical Cyclone Category 3
	Hurricane Category 2				
	Hurricane Category 3				
	Hurricane Category 4	Extremely Severe Cyclonic Storm		Intense Tropical Cyclone	Severe Tropical Cyclone Category 4
	Hurricane Category 5	Super Cyclonic Storm		Very Intense Tropical Cyclone	Severe Tropical Cyclone Category 5

forecast how a tropical cyclone evolves, including its track and change of intensity, when and where one will hit land and at which intensity. The TC forecasts are made available for up to 96 hours. Nevertheless, determining a tropical cyclone's exact location, time, and intensity at landfall remains challenging. It is worth noting that the effects of a TC start well ahead of the landfall and impacts could be felt long after landfall.

Over the years, predicting the track of tropical cyclones has improved greatly. However, figuring out how strong they will be, how much rain they will bring, and how high the storm surges will be hasn't improved as much. A method based on probabilities (the range of possible outcomes and how likely each one is) is being developed and applied to track, intensity, and related hazards.

Through its Members and Centres, the WMO community supports humanitarian action globally by providing authoritative weather, water, and climate information and expert advice. The WCM curates authoritative information to deliver situational awareness products to UN and humanitarian agencies like UNHCR, UN OCHA, and IFRC. In addition, the WCM facilitates liaison between humanitarian agencies and hydrometeorological and climate services. Information or dedicated support can be provided upon request (see WMO Coordination Mechanism: https://wmo.int/activities/wmo-coordination-mechanism-wcm).

K.3.3 Rapid impact estimation

GDACS rapid impact estimation: Within 30min from source update (usually every 6 hrs): automatic definition of alert level for humanitarian activation, this includes:

- Area potentially mostly affected (tropical cyclone track map)
- Event map
- Wind and precipitation forecast maps
- Storm surge calculations
- Intensity category wind polygons
- Exposed population to wind, rain and storm surge estimate (affected area in the tropical cyclone's wind category)
- Exposed critical infrastructure

Within GDACS, under the Satellite Mapping Coordination Systems (SMCS), satellite mapping information products also become available when the relative mapping services are activated.

K.3.4 Physical impact

Extension of the impact caused by a tropical cyclone varies with its size and intensity. Damages depend on the speed of the wind, the amount of rain, the height of the potential storm surge, flooding and the combination of all those hazards.

Weather and sea conditions can deteriorate substantively well ahead of landfall, and impacts will be felt long after landfall. The impacts caused by tropical cyclones can result in fatalities, displacement of populations, and damage to infrastructure, especially in densely populated areas. Coastal communities affected by a tropical cyclone's landfall are particularly vulnerable to such floods. The greatest damage to life and property is not from the wind itself but from rainfall and storm surges leading to flooding and landslides.

- Strong winds and floods caused by tropical cyclones can heavily damage infrastructure and buildings. High buildings are particularly vulnerable to hurricane force winds, as wind speeds tend to increase with height.
- In mountainous areas, these floods can be particularly harmful as heavy flash floods can lead to landslides and mudslides, especially in areas with saturated soils.
- Wind can disrupt telephone lines, antennae, and satellite disks, and damage high-voltage wires, causing power cuts.
- Crops, livestock, and fisheries in the affected area are likely to be damaged, as well as seeds and tools.
- Debris such as signs, roofing materials and small items left outside can turn into small missiles in strong winds and can lead to loss of life and damage to structures.
- Winds can cause trees to split and fall. Uprooted trees can damage underground utility lines.
- A certain amount of the destruction caused by cyclones results from debris hitting structures

that would normally be able to withstand the wind. Should the winds persist, the amount of debris will increase, causing additional damage and producing more debris.

K.3.5 Direct impact on the population

The direct impacts of tropical cyclones depend on the number of people living in low-lying coastal areas in the storm's direct path, the built environment, including building design, and whether there is sufficient time for warning and evacuation. High-density settlements in low-lying areas combined with poor housing construction amplifies risks. Storm surges, worsened with rain, leading to coastal inundation, is the primary direct cause of mortality following tropical cyclones.

- TCs can destroy businesses, farms, and fisheries, leading to immediate and often long-term income loss for individuals and families dependent on these sectors.
- TCs can destroy standing crops through high winds, flooding, and saltwater intrusion, leading to immediate food shortages. Flooding and structural damage can ruin stored food supplies, exacerbating food insecurity.
- High winds, flying debris, and flooding can cause the immediate death of livestock. Surviving animals may suffer injuries and are at increased risk of diseases due to exposure to the elements, contaminated water, and poor sanitary conditions post-cyclone. Grazing lands and stored feed can be destroyed, leading to food shortages for livestock. This can result in malnutrition and decreased productivity.
- TCs can directly and indirectly impact public health in various ways. Some of these include an increase in drowning and other physical injuries, a rise in the risk of water and vector-borne infectious diseases, disruption of health systems and facilities, leaving communities without access to healthcare, and causing damage to basic infrastructure like food and water supplies and safe shelter.
- A speedy response is crucial to prevent the spread of diseases. The disease risks are highest in overcrowded areas where water and sanitation standards have declined. This can occur when large populations are displaced from flooded areas and forced to stay in shelters without proper water supply.
- Flood waters may contain sewage and chemicals and hide sharp metal or glass objects, electrical lines, or dangerous snakes and reptiles, resulting in injuries, diseases, electrocution, and bites.
- Major population movements are rare but may occur in heavily damaged urban areas due to flooding or storm surges.
- Repeated TCs and the resultant damage to agricultural land can compromise long-term food security, making it harder for communities to recover and rebuild their food stocks.

K.3.6 Aggravating factors

Several factors can worsen the effects of a TC:

- **Winds:** Valleys with gradual slopes can increase wind speed, while deep, enclosed valleys offer wind protection. Surrounding dense forests can reduce wind force.
- **Rain and floods:**
    - Slow-moving and tropical storms that move into mountainous regions usually produce larger amounts of rainfall.
    - Bigger systems = more rainfall, slower systems = more rainfall.
    - The physical characteristics of the drainage basin, such as the soil type, the degree of saturation of the ground, and the vegetation that controls runoff.
    - The type of drainage system used has a notable impact on its expected discharge capacity. Closed systems that use pipes are more prone to blockages, making maintenance more challenging. Failure to maintain these systems can result in overflow and severe flooding in urban areas.
- **Storm surge:** Potentially disastrous surges can occur in low-lying coastal areas and across inland water bodies such as bays, estuaries, lakes, and rivers, leading to severe flooding. When the tide is high and combined with the storm surge, the total water level is higher, and the impacts are worsened.

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Buildings with lightweight structures and wood frames are most susceptible to damage during cyclones, particularly older buildings where the quality of wood has degraded over time. Houses made of unreinforced or poorly constructed concrete blocks are also at risk. Buildings constructed with mud are particularly vulnerable to heavy rainfall and flooding.

K.3.7 Typical needs

In case of large infrastructural damage, USAR teams may be needed to search for survivors trapped under damaged buildings. Similarly, Emergency Medical Teams (EMTs) may also be needed to treat injuries and diseases that occur in the aftermath of a tropical cyclone.

Violent winds and flooding may displace people. Shelters and evacuation centres, including all basic services regarding food, water, non-food items, sanitation, health services and safe places, will usually be a priority.

Food security – Distribution of non-perishable food items to address immediate food security needs, including provision of high-protein and high-calorie foods, especially for vulnerable populations such as children, pregnant women, and the elderly. Long-term strategies to rebuild and improve food production, including providing seeds and agricultural inputs for replanting crops is also needed.

WASH—Ensuring access to safe drinking water is a priority. This involves the immediate provision of bottled water or water purification tablets. Additionally, mobile water treatment units should be deployed, and household water filters should be distributed to further guarantee clean water access. Restoring damaged water supply systems, including the repair of wells, pipes, and treatment plants should be initiated as soon as possible. To prevent waterborne diseases and maintain hygiene, temporary sanitation facilities should be established, providing a critical component of the overall recovery strategy.

Agricultural assistance may include the provision of seeds, fertilizers, and tools to help farmers restart crop production and measures to address soil salinity and erosion caused by flooding and storm surges.
See also **Section K.4** on floods for more on typical needs.

K.3.8 UNDAC mission

UNDAC teams have often been sent to countries that are expected to be hit by a tropical cyclone as a preventive measure. Mobilization and deployment in such cases happen rapidly, as it is critical for the team to be on the ground before the cyclone makes landfall, ensuring that they can respond quickly and effectively.

- When pre-positioned, the first step should be establishing a working relationship with the National/Local Authorities and the RC/HC office. Together, you should assess the preparedness measures that have been put in place. At a minimum, you should agree on roles and responsibilities and the first actions to be taken after the tropical cyclone has passed. Supporting damage assessments, access, and humanitarian needs are typical first tasks for an UNDAC team, as well as preparing for facilitation of coordination for possible incoming international response.
- If the team has been pre-positioned in a country expected to be hit by a tropical cyclone, it is of utmost importance to locate a safe place to shelter when the storm makes landfall. UNDAC members must be prepared to be in lockdown during the period while the tropical cyclone passes and should be deployed with enough food and water to carry them over. It may take several days before it is safe to start any substantial work, and communications and power may be cut off during this period.

During the mission, work and rest areas should be established in a strategically central position for the relief operation, co-located with or close to the National Emergency Management Agency's (NEMA) Emergency Operation Centre (EoC).

K.3.9 Safety concerns

Safe shelter during tropical cyclones should be in modern reinforced concrete buildings that follow building norms, including risk mitigation measures. Structural engineers can advise on this. The building should be located away from other installations, like power masts and cables, etc., that may fall and damage it. Preferably, it should be on high ground that is not susceptible to flooding.

Because there is a high risk of power loss, it is advisable to procure a generator and enough fuel to sustain operations while in lockdown.

See also floods **Section K.4.**

K.4 Floods

Floods are naturally occurring seasonal phenomena that play a vital role in maintaining soil fertility. They do so by depositing fresh layers of sediments, sand, and gravel and flushing salt out of soils. Coincidentally, floods are also one of the most widespread natural-hazard-related disasters in scope and severity.

Floods can be either local, affecting a neighbourhood or community, or very large, affecting entire regions. The pattern of floods across all continents has been changing over the last decades. In many regions, floods are becoming more frequent, intense, and impactful for local communities, particularly because the number of people living in areas vulnerable to flooding is increasing due to poverty, governance and development challenges.

Heavy rain is the primary cause of significant riverine floods. Brief torrential rain, which can generate flash floods, is the second leading cause. Both of these types of rains can be created by a variety of weather phenomena, including winter depressions, atmospheric rivers, tropical cyclones, and seasonal monsoon rains. See also **Section K.3** Tropical Cyclones. Other natural processes, such as snowmelt, can also lead to flooding. Additionally, inadequate drainage in urban areas and failure of levees and dams can contribute to flooding.

There are various types of floods, including river floods, which is the most common type, coastal floods, flash floods, groundwater floods, ice-jam floods, ponding floods, snowmelt floods, surface water flooding, and glacial lake outburst floods.

- **River flood –** This is a temporary increase in the water level of a stream or body of water that reaches a peak and then recedes at a slower pace. These floods can happen in various river and catchment areas. They usually occur on flood plains or washlands when the water flow exceeds the capacity of the stream channels, and water spills over the natural banks or artificial barriers. River floods are primarily caused by prolonged precipitation events upstream from the affected area. However, they can also occur when traditional flood-control structures, such as levees and dikes, are overtopped.
- **Flash flood –** This is a type of flood that occurs quickly and with a high peak discharge. It usually happens within 3-6 hours of heavy rainfall, and it is limited to small water basins with steep slopes. Flash floods are highly localised and can cause raging torrents that sweep away everything in their path. They can occur due to various reasons, such as dam or levee failure, sudden release of water in a previously blocked passage, or heavy debris or ice that obstructs the riverbeds. These floods can be extremely dangerous, especially in urban areas or mountain canyons.
- **Coastal flooding –** This is a type of flood that usually occurs due to storm surges and high winds combined with high tides. The surge is a consequence of rising sea levels caused by low atmospheric pressure, especially near major estuaries or confined sea areas. When water accumulates in an area, it can become more intense due to two factors. Firstly, the seabed may become shallower, causing the water to pile up. Secondly, the flow of water back towards its source may be slowed down, which amplifies the buildup of water in that area.

K.4.1 Early warning

Except for flash floods[2], it is possible to reasonably predict river floods and coastal floods. By using weather forecasts to determine expected precipitation levels, combined with in-situ observations of soil moisture, snow or antecedent water levels and hydrologic/hydrodynamic models it is possible to make predictions of flooding.

Local prediction systems are available in many regions. Globally, floods can be forecasted through the Copernicus Global Flood Awareness System (GloFAS) and its Rapid Risk Assessment (RRA) tool. The RRA provides information on the hazard, including its timing, spatial distribution, magnitude, and details on the potentially exposed population, administrative divisions, settlements, and critical infrastructures. GDACS is currently developing full integration of the RRA into the floods section to automatically forecast major flood events.

K.4.2 Rapid impact estimations

GDACS rapid impact estimation: Within <15min from the source update, there is an automatic definition of alert level for humanitarian activation, this includes:

- Areas that mostly affected,
- Event map,
- Meteorological forecast map
- Exposure estimates (affected area polygons
- Reported casualties.

Within GDACS, under the Satellite Mapping Coordination Systems (SMCS), satellite mapping information products also become available when the relative mapping services are activated.

K.4.3 Physical impact

It is natural for rivers to overtop their banks with higher or lower frequency and spread out over their natural catchment areas. Human settlements and infrastructure in flood-prone areas can worsen the impact of floods, causing damage to property and loss of life.

- Flooding can cause significant damage by carrying a large amount of debris, such as sediment, silt, and organic material, which can obstruct and damage drainage channels, bridges, public roads, thoroughfares, and homes. Electricity is often interrupted in flood-affected areas.
- Structural damages after floods are common, as buildings may be swept away by water, inundated, collapse, or become damaged by the impact of floating debris.
- Floods can erode the ground under buildings and render them useless.
- Landslides and mudslides are common after heavy rains when saturated soils cause rock, earth, or debris to move down slopes.
- Containers of toxic substances can be carried away and their contents may be released.
- Flooding can dislodge landmines that had been under the surface or buried in riverbanks.
- Floods have the capacity to change the direction of rivers, which can disturb transportation, infrastructure, and agriculture over a vast area. Valleys are usually more adversely affected than open areas. The losses incurred are not limited to direct damages alone; indirect losses can also be significantly higher. Crops, food stocks, livestock, seeds, and tools in the impacted area may be lost.
- Freshwater floods carry suspended solids that leave mud and soil behind when the waters recede, possibly causing interruptions in water mains. Saltwater floods can make water sources unusable due to the high salinity levels. There are no inexpensive treatment methods that can be used to remove salinity from saltwater.

K.4.4 Direct Impact on the population

- Even as low as 15 cm, fast-moving water can knock a grown person off their feet, and 40 cm deep water can carry away most automobiles.
- One of the leading causes of death during floods is drowning. Two-thirds of deaths associated

2 The Flash Food Guidance System (FFGS) is an initiative developed by the Hydrological Research Center to provide WMO members with guidance products for flash floods. See https://wmo.int/projects/ffgs and www.hrcwater.org for more information.

with flooding are from drowning, with the other third from physical trauma, heart attacks, electrocution, carbon monoxide poisoning and fire.

- Other health issues related to floods are usually caused by injuries, infections, and chemical hazards. Common injuries that may occur include lacerations or punctures caused by glass debris, nails, and electrical shocks. Hypothermia can also be a problem, especially for children who are trapped in floodwaters for extended periods. Exposure to flood waters and rain can increase the risk of respiratory tract infections due to loss of shelter and exposure.
- Floods often result in drinking water contamination. Furthermore, power cuts may interrupt water treatment and supply plants, increasing the risk of water-borne diseases and impacting the proper functioning of health facilities.
- Floods can potentially increase the transmission of communicable diseases, e.g., water-borne diseases, such as typhoid fever, cholera, leptospirosis and hepatitis A, and vector-borne diseases, such as malaria, dengue and dengue haemorrhagic fever, yellow fever, and West Nile Fever.
- Floods often cause a large number of people to be displaced in a short amount of time. The length of the displacement depends on the duration of inundation. Even after the water recedes, the living and working conditions of those affected may not necessarily improve. Longer-term humanitarian needs usually emerge when the flood victims return home.
- Flooding may also lead to the release of hazardous materials, gas, oil and chemical spills and subsequent contamination.

K.4.5 Aggravating factors

- Geography and climate, such as recurring seasonal heavy storms and high groundwater levels, are significant factors that affect the risk of flooding. Steep terrain tends to concentrate runoff into streams very quickly and is often a contributory factor.
- Changes in soil properties, such as burn areas resulting from wildfires, impervious soils, removal of surface vegetation, and excess runoff caused by warm rainfall on significant snowpack, can also contribute to floods. When warm weather follows a winter with heavy snowfall in higher elevations, this can cause a rapid thawing and lead to unusually high-water levels in runoff rivers and catchment areas.
- Neglected or poorly designed dams, constructions and residential sites in flood-prone areas, obstructions of drainage channels, sewage treatment plants, waste dumps, or hazardous industries in low-lying areas can all contribute to the severity of flooding and its impact on communities.
- Communities located downstream from dams, low-level housing, and mud-built houses are all at risk of flooding.
- Lack of holistic flood risk mitigation planning along large river basins can make floods worse. For example, if communities upstream build levees on natural catchment areas, it may lead to excess water that gains force and creates more severe floods for communities further downstream.

K.4.6 Typical needs

- In the event of a large-scale flood, the immediate priority is to evacuate individuals from high places like rooftops and trees where they may have sought refuge from the rising water.
- Floods often result in a large number of displaced people in need of shelter solutions, evacuation centres, including all basic services regarding food, water, non-food items, sanitation, health services and safe places.
- Sewage systems may be flooded, resulting in overflowing wastewater that may contaminate drinking water sources and increase the risk of water-borne and communicable diseases. Stagnant water may become breeding spaces for insects and increase the risk of vector-borne diseases. Water purification units may be a priority.
- Epidemiological surveillance and disease control including:
  - Medical diagnosis and treatment
  - Vector control measures
  - Vaccination against Hepatitis A
  - Malaria prevention
  - Hygiene and health education awareness raising and promotion.

- In large floods, access to several areas by road becomes difficult or impossible. The road network will highly likely be underwater in several places, and bridges and fords may be damaged or flooded. In such situations, aerial assets such as helicopters may be the only way to reach people who are cut off and can't be reached by land.
- Emergency situations also tend to exacerbate existing inequalities among the population and lead to a rise in human rights and protection concerns. Large displacements can worsen existing inequalities and raise protection risks. Special considerations should be given to known protection risks in the context. See also **Chapter G.2** Centrality of protection and Quality Response. A breakdown of social structures and services can result in increased risks of exploitation, abuse, and neglect for vulnerable groups, and relief efforts must prioritize the unique needs of these groups to ensure their safety and well-being. Women and children often face heightened vulnerability and are disproportionately affected. Female-led households may have less access to resources, financial independence, and decision-making power, which complicates their ability to recover. Children are particularly susceptible to physical harm and psychological trauma. They may be orphaned, and displacement often disrupts their education and routine, leading to long-term challenges.
- Informal settlers in coastal areas or close to waterways are also more vulnerable as housing is poor and after a flood their lack of land rights are exposed.

K.4.7 UNDAC mission

- Depending on which natural hazard precedes the flood, e.g., windstorms, prolonged or torrential rains, etc., the UNDAC mission may either be sent ahead of the forecasted weather as pre-positioning or be mobilised after the flood has occurred. In the latter cases, deployment will often take a few days while the mission Terms of Reference (ToR) are discussed with the RC/HC and/or OCHA regional office.
- During the mission, work and rest areas should be established in a strategically central position, on a high ground not prone to flooding, for the relief operation, co-located with or close to the National Emergency Management Agency's (NEMA) Emergency Operation Centre (EoC). The flooded area may be very large however, and finding a central position may be challenging. In these situations, several UNDAC hubs (sub-OSOCCs) may be needed.
- A separate UNDAC flood response guideline can be found in the UNDAC Toolbox.

K.4.8 Safety concerns

The possible impact on water and sanitation services will also impact the UNDAC team. Pay particular attention to hygiene and preventing waterborne, vector-borne, and communicable diseases. Use mosquito nets and repellents and consider if malaria prophylaxis is necessary.

Exercise caution and use Personal Protective Equipment (PPE) when entering premises/structures that have suffered flood damage. The respiratory effects of dampness and mould can cause serious illness and can be fatal in more severe cases. The respiratory effects include general symptoms such as cough, wheezing, and shortness of breath, as well as an increased risk of airway infections, including aspergillosis, i.e., an infection of the airways by the fungus Aspergillus.

Possible access issues may necessitate travel by small boats. Boat safety procedures, such as wearing life vests and being aware of life rafts, should be given special attention.

Travel by road may involve crossing areas that are flooded or eroded from water damage or landslides. Special attention should be given to safety procedures for crossing roads immersed in water, and subject matter experts should consider whether the road can be used by light and/or heavy vehicles.

K.4.9 Security concerns

Normal precautions depending on context and the safety & security briefing from UNDSS.

K.5 Volcanoes

Volcanic activity is responsible for direct and indirect different hazards associated with lava flows, lava domes, ash or tephra fallout, volcanic gases, ballistics, pyroclastic density currents, debris flows, lahars and floods. These are all consequences at the ground surface triggered by the movement of magma below the earth's surface or its direct emergence under subaerial conditions. The violence of volcanic activity on the earth's surface depends on the pressure of the gases dissolved in the magma.

There are two main types of volcanic eruptions: effusive and explosive. Effusive eruptions occur when almost no gas is dissolved in the magma, causing a slow and quiet flow of lava to the surface. Effusions of lava commonly continue from days to months, occasionally for years. Velocity of the lava front depends on magma viscosity. When viscosity is high, lava flows propagate very slowly, so it can generally be avoided by exposed population. Explosive eruptions occur when large quantity of pressurized gas is dissolved in the magma, leading to violent explosions that produce ash, tephra, ballistics and pyroclastic debris.

Each has very different dynamics, also regarding time and area of impact. A volcanic eruption, with all the related hazards, can last from a few days to years. Its dynamic can be detected within minutes or days, and it can affect from a few square kilometres to hundreds of square kilometres or to the entire planet.

In most cases, a combination of different volcanic activities may occur during the same volcanic eruption, e.g., ground shaking, lava flow, gas, ash emissions, etc. Explosive eruptions are considered the most dangerous, as alert time is short and limits possible evacuation of areas of risk. Moreover, it is usually extremely challenging to determine when a volcano may provoke an explosion, even in presence of clear precursor signals of it.

During an effusive eruption, the speed of lava depends on its viscosity, and it can initially reach several kilometres per hour for low viscosity (basaltic) magma. However, within a few hours, it can slow down to a walking pace or less. On steep slopes, the velocity of some lava can be as high as tens of kilometres per hour.

Basaltic lava flows can extend from 1 to 10 kilometres, with some reaching over 30 kilometres and even 50 kilometres. These types of lava flows can also be 3 to 20 meters thick. Historical lava flows on land have typical volumes between 0.01 and 0.1 km3, but in some cases, the flow fields can be exceptionally large and exceed 10 km3.

More viscous lava (andesitic), on the other hand, are travelling usually shorter distances, ranging from 5 kilometres in length, up to tens of kilometres and typically advances at rates of 0.1 km per day or even less. After an eruption, some parts of lava flows may remain molten, which can extend the lava advancement time. Lava flow with andesitic composition may vary in thickness from 20 to 300 meters, with volumes typically ranging from 0.01 to 0.1 km3. However, in some cases, they can be as large as 10 to 20 km3.

A lava dome is a volcanic edifice created by the emergence of very viscous (andesitic) magma at the surface. Lava domes generally grow slowly and do not pose an imminent danger to a population, but they may collapse to generate hazardous pyroclastic flows.

Historically, pyroclastic flows have been the deadliest of all volcanic activity types. Pyroclastic flows are hot, dense, fast-moving flows of lava pieces, volcanic ash, and hot gases that move extremely quickly across the ground surface at velocities of tens to hundreds of kilometres per hour and have temperatures typically between 200 and 600°C. They typically originate from the gravitational collapse of explosive eruptive columns and lava domes. Most pyroclastic flows spread between a few to tens of kilometres from the source. For exceptionally large-magnitude events, pyroclastic flows may travel over 100 km and cover areas of up to hundred km2.

Two different flow parts commonly form pyroclastic flows: a dense basal undercurrent and a diluted upper part whose motion is mainly dominated by turbulence. The dense basal part strongly interacts with (and is controlled by) the topographic surface as it erodes and deposits material along its path. The diluted upper part tends to be less controlled by topography and may decouple from the main dense undercurrent, overcoming topographic obstacles and following other paths.

When a pyroclastic flow impacts the sea surface, its large momentum may be transferred to the water, generating a tsunami. In such a case, the volcanic eruption can have indirect consequences for the population living in the coastal area, also hundreds of kilometres from the volcano.

K.5.1 Early warning

Knowledge of possible eruption sites, the travel distance a lava flow, the height of a volcanic column, the distance a pyroclastic flow can travel, the area of the possible volcanic ballistics and ash fall, the speed of the flow front, and the affected area is crucial for assessing hazards related to volcanic activities.

If a volcanic area is well-monitored, the movement of magma towards the surface may be detected days, weeks, or even years before an eruption. This enables planning, preparation, and emergency actions such as evacuation of the exposed population.

Monitoring lava-dome extrusion rates and topography in high resolution, both spatially and temporally, can allow for the anticipation of dome collapse pyroclastic flows, leading to timely evacuation of the population.

K.5.2 Rapid impact estimations

GDACS rapid impact estimation: issued within □ 1hr from source update (upon expert assessment); manual definition of alert level for humanitarian activation, this includes:

- Potential area mostly affected,
- Event map,
- Volcanic ash detected and forecasted by Volcanic Ash Advisories (VAA),
- Meteorological forecast map,
- Exposure estimate (affected countries, critical infrastructures, population affected in various distances from eruption source).

Within GDACS, under the Satellite Mapping Coordination Systems (SMCS), satellite mapping information products also become available when the relative mapping services are activated.

K.5.3 Physical impact

- During an eruption, a volcano can eject large quantities of volcanic material, known as tephra, into the atmosphere. This can include ash, small rocks, and volcanic bombs, i.e., larger rocks. Tephra fallout can cause damage to human health (respiratory issues), buildings, infrastructure, and agriculture, particularly if the accumulation is heavy.
- Lahars are fast-moving mudflows or debris flows that occur when volcanic material mixes with water, either from rainfall, melting snow, or the melting of ice and snow on the volcano. Lahars can travel many kilometres downstream, burying everything in their path, causing significant destruction.
- Lava can flow from a volcano's vent, destroying everything in its path, including buildings, roads, and vegetation. Although lava flows usually move slowly enough to allow for evacuation of at-risk communities, they can still pose a significant threat to them. Inundation, burial, fire, and explosion may damage buildings, infrastructure, communications, agriculture, and the environment.
- Damage may not be complete, but partial burial or inundation by lava generally makes buildings, infrastructure and land unusable. Buried infrastructure may also be destroyed due to thermal impacts.
- Pyroclastic flows can kill all living things and destroy structures by abrasion, impact, burial and heat.
- Escape routes may be cut off, or lava may trigger explosions on melting snow, ice and water, or flammable fluids.
- Lava flows may ignite forest or urban fires.
- Volcanic gases and aerosols (air pollution) need to be considered, possibly over large areas. Volcanic eruptions release various gases, including sulphur dioxide, carbon dioxide, and hydrogen sulphide, into the atmosphere. These gases can have adverse effects on air quality and can

contribute to respiratory problems, acid rain, and climate disruption.

- Ashfall can blanket vast areas, causing respiratory problems, damaging crops, and disrupting transportation and infrastructure.
- Volcanic eruptions can cause environmental damage, including habitat destruction, soil erosion, and contamination of water bodies. Lahars (mudflows) and ash deposition can alter landscapes and ecosystems, affecting biodiversity and ecosystem services.
- Ashfall can damage crops, contaminate water sources, and disrupt livestock grazing, leading to agricultural losses and food shortages. Ash can also coat vegetation, making it difficult for plants to photosynthesise and affecting ecosystems.
- Prior, before and during volcanic eruptions, the ground around the volcano may deform by swelling or sinking. This deformation can damage infrastructure, such as roads and buildings, and can also lead to landslides and other geological hazards.
- Volcanic eruptions can trigger secondary events such as earthquakes, landslides, and avalanches, which can cause further damage and complicate rescue and recovery efforts.

K.5.4 Direct impact on the population

- Volcanic eruptions can lead to injuries or fatalities due to tephra fall, pyroclastic flows, lahars, and other types of volcano-related natural phenomena. Deaths commonly result from thermal injury, including laryngeal and pulmonary oedema, asphyxiation, and impact or blast trauma.
- Harmful gases, ash, and other pollutants can be released into the air, leading to respiratory problems, eye irritation, skin irritation, and other health issues. Exposure to volcanic ash can also increase the risk of lung diseases.
- Injuries may occur if individuals walk on a lava carapace too thin to carry the weight of a person when there is molten lava below the outer shell.
- The risk of a volcanic eruption can force the evacuation of nearby communities due to the immediate dangers posed by lava flows, ashfall, pyroclastic flows, and other hazards.
- Psychosocial effects may include anxiety, stress, grief, and trauma resulting from loss of life, displacement, property damage, and disruption of daily life. Social cohesion may be strained, and vulnerable populations may face heightened risks. Long-term displacement, if combined with loss of livelihoods and homes, may cause longer-term mental and physical health impacts. The long-term cascading effects can be more severe than immediate impacts.

K.5.5 Aggravating factors

- The composition of magma (molten rock beneath the earth's surface) can influence the explosiveness of an eruption. Magma with high viscosity and gas content tends to produce more explosive eruptions as gas bubbles become trapped, and pressure builds up before release.
- The presence of gases, such as water vapour, carbon dioxide, sulphur dioxide, and others, dissolved in magma can influence eruption dynamics. Increased gas content can lead to more explosive eruptions by driving rapid expansion and fragmentation of magma as it reaches the surface.
- Tectonic forces, such as plate movements and interactions between tectonic plates, can influence volcanic activity by affecting the movement and storage of magma beneath the Earth's surface. Subduction zones, where one tectonic plate is forced beneath another, are often associated with volcanic arcs and explosive eruptions.
- The interaction between magma and groundwater can lead to eruptions where water is rapidly vaporised by heat from magma, causing extremely explosive fragmentation of rock and ash generation. This process can occur when magma encounters water-saturated rocks or aquifers.
- The eruption history of a volcano can influence future eruptions by affecting the state of the volcanic edifice, magma plumbing system, and surrounding landscape. Volcanoes with a history of explosive eruptions may be more likely to experience similar events in the future.
- External triggers, such as earthquakes, landslides, or human activities, e.g., mining, geothermal drilling, can sometimes initiate or influence volcanic eruptions by disturbing the stability of volcanic systems or causing changes in pressure and stress within the Earth's crust.

- High population density in volcanic hazard zones increases the number of people at risk during an eruption. Settlement patterns that place communities close to active volcanoes can lead to greater exposure to volcanic hazards, including lava flows, pyroclastic flows, and ashfall.
- Urban areas near volcanoes may have dense infrastructure, including buildings, roads, and utilities, which can be vulnerable to damage during eruptions. Poorly constructed or informal housing may be particularly susceptible to collapse or damage from volcanic hazards.
- Socioeconomic disparities can exacerbate the impact of volcanic eruptions, as marginalized communities may have limited access to resources, infrastructure, and social support networks. Vulnerable populations, such as low-income households, indigenous communities, and informal settlers, may face greater challenges in preparing for and recovering from volcanic disasters.
- Lack of access to accurate information about volcanic hazards, evacuation procedures, and emergency preparedness measures can hinder community resilience and increase vulnerability to volcanic disasters. Education and awareness-raising efforts are essential for empowering communities to make informed decisions and take proactive measures to reduce risk.
- Weak institutional capacity, inadequate disaster response planning, and limited disaster management resources can hamper effective preparedness and response efforts. Communities may lack access to information from early warning systems, evacuation plans, shelters, and emergency supplies needed to cope with volcanic emergencies.
- Volcanic eruptions can disrupt local economies that rely on tourism, agriculture, or other industries at risk of volcanic hazards. Economic dependencies may create incentives to downplay volcanic risks or prioritize short-term economic gains over long-term hazard mitigation measures.

K.5.6 Typical needs

- Attempts during ongoing eruptions to halt or divert flows by erecting barriers, spraying lava with water, or breaking the margins of lava channels have had mixed success. Nevertheless, barriers have been constructed alongside new high-value assets in some areas with volcano hazard risks.
- Many people may be displaced from their homes due to volcanic ash, lava flows, or other hazards. Providing emergency shelter is crucial to ensure the safety and well-being of those affected. Evacuation remains the most effective strategy for protecting life and health from primary and secondary hazards.
- Injuries such as burns, respiratory problems from ash inhalation, and trauma from falling debris are common. Medical care facilities may be overwhelmed, so setting up temporary clinics and providing medical supplies and personnel is crucial.
- Eruptions can contaminate water sources and destroy crops, leading to shortages of food and clean water. Providing access to safe drinking water and distributing food supplies is essential.
- Immediately after a volcanic eruption, people may be isolated, trapped or injured in affected areas. Lava flows and landslides may have cut off evacuation routes. Search and rescue teams may be needed to locate and evacuate survivors.
- Emergency situations also tend to exacerbate existing inequalities among the population and lead to a rise in human rights and protection concerns. Land rights issues related to long-term evacuation may be a concern for informal settlers. Special considerations should be given to known protection risks in the context. See also **Chapter G.2** Centrality of protection and quality response. A breakdown of social structures and services can result in increased risks of exploitation, abuse, and neglect for vulnerable groups, and relief efforts must prioritize the unique needs of these groups to ensure their safety and well-being. Women and children often face heightened vulnerability and are disproportionately affected. Female-led households may have less access to resources, financial independence, and decision-making power, which complicates their ability to recover. Children are particularly susceptible to physical harm and psychological trauma. They may be orphaned, and displacement often disrupts their education and routine, leading to long-term challenges.

K.5.7 UNDAC mission

UNDAC missions to volcanic eruptions have, in many cases, been initiated when early warning indicates a risk of an eruption. The affected country and the RC/HC have asked for specialist support with volcano risk assessment, evacuation planning, and setting up coordination support services.

Team composition in these cases requires a complementary set of skills spanning subject matter expertise in volcano risk management, environmental experts, and general disaster risk management. Collaboration with the United Nations Environment Programme (UNEP)/OCHA Joint Environment Unit (JEU) and UNDAC's Operational Partners, like the EU Civil Protection Mechanism, is often necessary to put the right team of experts together.

Given the quality of early warning systems, there is often time to mobilise and compose a team with the right complementary skillsets and plan the mission properly before deploying. Typical mission objectives may include:

- Support the development of contingency and evacuation plans and be ready to support any response activities should the need for complete evacuation occur.
- Provide technical advice to local and national authorities to identify, assess, and mitigate negative environmental impacts induced by volcanic activities.
- Provide technical advice on volcanic (ongoing or possible) activities, dynamics, impact on nature and ecosystems, environmental toxicology, ash management, disaster waste management and environment in humanitarian action.

K.5.8 Safety concerns

There is a risk of exposure to tephra fall and volcanic gases, and regular monitoring of air quality should be conducted. This service is normally provided by national meteorological agencies, and UNDAC teams should check if the recorded average levels of suspended particles and gases are below the exposure limits recommended by the World Health Organization (WHO).

If ash falls, it may clog water and air filters. As a contingency, access to clean water should be secured before an eruption occurs.

A large quantity of ash in the atmosphere may create problems for air traffic, and consequently, reaching the areas affected by the eruption by helicopters and/or small airplanes could be very difficult or impossible.

The exposure to volcanic gases and particles can be mitigated with proper safety equipment like gas masks. UNDAC members should either bring them from their home base or check if they can procure them in-country.

Extreme caution must be exercised when moving near volcanic eruptions, as lightning strikes appear to occur most frequently around volcanoes with large ash plumes.

K.5.9 Security concerns

Normal precautions depending on context and the safety & security briefing from UNDSS.

K.6 Wildfires

Wildfires can be defined as any unplanned or uncontrolled fire affecting natural, cultural, industrial and residential landscapes. Wildfires play a natural role in many ecosystems by clearing out dead vegetation, promoting new growth, and recycling nutrients. However, when they occur in populated areas or under extreme conditions, wildfires can become destructive disasters, causing widespread damage and economic losses.

Wildfires are either started by natural causes, e.g., lightning, occasionally by burning coal seams or volcanic activity, etc., or – predominantly at global level – by human activities primarily linked to vegetation management through the burning of live or dead vegetation in natural or anthropogenically altered ecosystems. These include natural lands such as forests, grasslands, bush (shrub, scrub), terrain with high organic matter content (peatlands, wetlands), as well as human-managed lands such as cultivated lands (agricultural and pasture lands, plantations, abandoned formerly cultivated lands).

Wildfire occurrence, characteristics, and impacts are sometimes linked to other hazards, like droughts, heat waves, and extreme weather events, which can influence fire intensity, spread, and severity and thus the duration, size, and controllability of wildfires.

K.6.1 Early warning

A component of the Copernicus Emergency Management Services is dedicated to enhancing wildfire prevention and assessing wildfire impacts and is referred to as the European Forest Fires Information System (EFFIS). It aims to provide early warning, and increase firefighting preparedness and efficiency, and to monitor the impact of damages caused by wildfires. EFFIS is currently focused on Europe, but its global reach is advancing through the development of a similar service through the Global Wildfire Information System (GWIS).

K.6.2 Rapid impact estimations

- Mathematical models were developed in the 1940s to predict wildfire behaviour. These models have been continuously evolving over the years. They take into account various factors and their complex relationships, such as the type of fuels (grass, shrub, small or large trees in their horizontal and vertical disposition on the ground), weather conditions (wind speed and direction, temperature, and relative humidity), the terrain's topography.
- Modelling wildfires and forecasting fire behaviour can anticipate the direction and intensity of the fire, which can be crucial for efficient evacuation and fire suppression. The models can also predict the spread of the fire and forecast smoke pollution, which helps protect human life and infrastructure.
- Some national and international disaster management organizations are exploring the use of artificial intelligence (AI) to analyse historical and real-time data sources such as weather, topography, fuel conditions, etc., using algorithms to forecast fire behaviour.
- Satellite data provide information on burnt areas and emissions. Among other data, GWIS provides statistics on the average area burnt, the number of fires, emissions and fire danger conditions by region and country on a global scale.

K.6.3 Physical impact

Wildfires can have severe and long-lasting physical impacts on natural ecosystems and human communities.

- Wildfires can damage or destroy infrastructure such as homes, buildings, roads, power lines, and telecommunications equipment. This can disrupt communities, affect national critical infrastructures, like hospitals, national grid, and transport systems, impede emergency response efforts, and require extensive resources for repair and rebuilding. The physical damage caused by wildfires can result in significant economic losses, including property damage, loss of crops or timber, and impacts on tourism and outdoor recreation industries.
- Wildfires affecting the remnants of human activities, like waste deposits, remediated and un-remediated mine sites, contaminated lands, etc., may result in co-burning and subsequent release of hazardous/toxic substances.
- Wildfires produce large amounts of smoke, particulate matter, and other pollutants, which can degrade air quality over wide areas. This can have significant health impacts on people, especially those with respiratory conditions, and can also affect visibility and aviation operations.
- Water quality will be impacted by wildfires as they deposit ash and other pollutants into water bodies, contaminating drinking water supplies and aquatic habitats. Runoff from burned areas can also increase the risk of flash flooding, soil erosion and pollution of downstream watersheds.
- Wildfires can destroy large areas of vegetation, including trees, shrubs, and grasslands. This loss of vegetation can disrupt ecosystems, reduce biodiversity, and lead to soil erosion and loss of habitat for wildlife. They can alter soil properties, leading to changes in soil structure, nutrient levels, and water retention capacity. This can impair soil fertility and productivity, making it more

difficult for vegetation to regrow and increasing the risk of erosion and sedimentation.

- The effects of wildfires on vegetation cover and soil stability may also create secondary hazards, such as postfire landslides, mudslides, flash floods, erosion and siltation, i.e., the dirt, soil, or sediment that is carried and deposited by water. While some silt in water is normal and healthy, many additional tons of silt may negatively impact water quality.

K.6.4 Direct impact on the population

- Wildfires produce smoke and other pollutants that can worsen air quality, leading to respiratory problems such as asthma, bronchitis, and exacerbation of existing conditions. In severe cases, exposure to wildfire smoke can cause acute respiratory distress and other serious health issues. Certain populations are particularly vulnerable. Wood smoke has high levels of particulate matter and toxins. Respiratory morbidity predominates, but cardiovascular, ophthalmic, and psychiatric problems can also result. Large areas of contaminated atmosphere may require the use of facemasks.
- Direct exposure to wildfires can result in injuries or fatalities, particularly for firefighters and residents in affected areas. Burns, smoke inhalation, and trauma from fire-related accidents are common risks during wildfire events. Severe burns resulting from direct contact with the fire require care in special units and carry a risk of multi-organ complications.
- Wildfires can have lasting psychological and emotional effects on individuals and communities, including feelings of fear, grief, and trauma. The uncertainty of evacuation, loss of property, and witnessing the destruction of natural landscapes can take a toll on mental well-being and contribute to post-traumatic stress disorders and other mental health issues.

K.6.5 Aggravation factors

- Sustained winds can aggravate the intensity and duration of wildfires. Dry, hot, and windy weather conditions create ideal conditions for wildfires to ignite and spread rapidly. Low humidity levels and high wind speeds can fan flames, increase fire behaviour, and make firefighting efforts more challenging.
- Droughts reduce fuel moisture content, enhancing flammability and increasing the amount of dead matter susceptible to fire (dead branches, foliage). The availability and dryness of fuel, such as vegetation and dead organic matter, significantly influence wildfire behaviour.
- Excessive plant growth and accumulation of flammable debris can increase fuel loads, making fires more intense and difficult to control.
- The terrain and topography of an area can affect the behaviour and spread of wildfires. Steep slopes, canyons, and valleys can channel and accelerate fire spread, while changes in elevation and aspect can influence wind patterns and fire behaviour.
- The type, density, and flammability of vegetation play a significant role in determining wildfire behaviour. Dense forests with highly flammable trees and shrubs are more prone to intense wildfires, while grasslands and chaparral ecosystems can also support rapid fire spread under conducive conditions.
- Fires burning on terrain contaminated by radioactivity may lead to uncontrolled re-distribution of radioactive particles.
- Wildfires burning into industrial areas and waste deposits may generate toxic pollutants.
- Fires burning on terrain bearing unexploded ordinance and land mines could result in injuries and fatalities.

K.6.6 Typical needs

- Evacuation to safe areas is the main priority during wildfires. Individuals and families may require temporary shelter, including emergency shelters, transitional housing, or accommodations with friends and family members.
- International assistance may be needed with Ground Forest Fire Fighter (GFFF) teams and modules specially designed for international deployments, including aerial FFF assets, which should plug into the national incident command system (ICS) for wildfires.
- Access to food and clean water is essential for the well-being of affected populations, particularly those who have been displaced or are unable

to return to their homes due to damage or evacuation orders.

- The distribution of emergency supplies such as non-food items, such as clothing, bedding, hygiene articles, etc., can help meet the basic needs of affected individuals and families, particularly those who have lost possessions or been evacuated from their homes.
- Access to medical care, first aid services, mental health support, and medication is critical for treating injuries, respiratory problems, and other health issues requiring medical attention.
- Wildfires can cause emotional distress, trauma, and anxiety for affected individuals, including survivors, evacuees, and first responders. Providing psychosocial support, counselling services, and community-based mental health programs can help address emotional needs and promote resilience.
- Emergency situations also tend to exacerbate existing inequalities among the population and lead to a rise in human rights and protection concerns. Special considerations should be given to known protection risks in the context. See also **Chapter G.2** Centrality of protection and quality response. A breakdown of social structures and services can result in increased risks of exploitation, abuse, and neglect for vulnerable groups, and relief efforts must prioritize the unique needs of these groups to ensure their safety and well-being. Women and children often face heightened vulnerability and are disproportionately affected. Female-led households may have less access to resources, financial independence, and decision-making power, which complicates their ability to recover. Children are particularly susceptible to physical harm and psychological trauma. They may be orphaned, and displacement often disrupts their education and routine, leading to long-term challenges.

K.6.7 UNDAC mission

UNDAC missions to wildfires are rare but may take place in situations where national firefighting capacities are exhausted, and the affected country asks for international support. UNDAC has been mobilised in cases of large-scale wildfires that become a national emergency and cause long-lasting pollution. In such cases, the typical response needs have been with GFFF teams, aerial FFF assets, emergency medical teams, and environmental experts.

Supporting the affected country with evacuation planning, coordination of international support and environmental assessments will be typical mission objectives in these cases. Environmental experts may be deployed alongside the UNDAC team.

When international GFFF teams, aerial FFF assets, and other firefighting assistance are deployed, UNDAC may have to establish a Reception/Departure Centre (RDC) and systems similar to a USAR Coordination Cell (UCC) to assist national ICS with coordinating international assistance. While INSARAG does not focus on FFF, OCHA can engage the network when affected governments are seeking advice or support in FFF. See also **Section G.10.1**.2 INSARAG coordination locations.

K.6.8 Safety concerns

The behaviour of wildfires can be difficult to predict as they can change direction and intensity based on weather, topography, and fuel availability. At the resting place and UNDAC office, the team needs to have an evacuation plan in place and be familiar with evacuation routes and assembly points. If the plan entails evacuating by car, keep vehicles fuelled and ready to go, and have an emergency kit in the vehicle with essential supplies. Follow evacuation routes and avoid driving through areas with active wildfires or heavy smoke.

Consider wearing protective clothing, including long sleeves, long pants, sturdy shoes, and a have a facemask or gasmask available to reduce exposure to smoke and ash. Carry a flashlight, mobile phone, and emergency supplies with you.

Limit outdoor exposure and avoid inhaling smoke and ash by staying indoors with windows and doors closed. Use air purifiers or filters to improve indoor air quality.

Exercise caution when moving near structures (domestic/industrial) near fire-active areas or where fires have been extinguished and hot embers are still live. In remote woodland areas, structures usually have their own sewage disposal systems via underground septic tanks, rich in Methane and Hydrogen Sulphide gases, which, under ideal vapour-to-air mixture conditions, can form an explosive mixture in contact with an ignition source like hot embers.

In heavy woodland areas prone to wildfires, one usually finds sawmills using a variety of chemicals in bulk for different purposes, including wood processing and preservation. Common chemicals include Chromated Copper Arsenate (CCA); Alkaline Copper Quaternary (ACQ); Copper Azole (CA) and Boric Acid. Other chemicals such as Calcium Chloride are used to control dust in saw mill environments. Reference should be made to their respective Material Safety Data Sheets (MSDS) to obtain relevant PPE and safety information.

K.6.9 Security concerns

Normal precautions depending on context and the safety & security briefing from UNDSS.

K.7 Droughts

Droughts are climate extremes characterised by persistent unusual dry weather conditions affecting the hydrological balance. The conditions are usually associated with lack of precipitation, deficit in soil moisture and water reservoir storage. Consequently, conditions on the ground are such that they can affect socio-economic sectors as well as ecosystems. Drought is usually a slow-onset hazard and complex phenomenon that intensifies over time and is often defined based on specific needs across different spatial and temporal scales.

A flash drought is a type of drought that develops very quickly, typically within a few weeks, and is characterized by a rapid onset of severe water shortages. Unlike traditional droughts, which can develop and persist over months or even years, flash droughts occur suddenly and are often triggered by a combination of factors such as high temperatures, low humidity, strong winds, and a lack of precipitation. These conditions lead to rapid soil moisture depletion, stressing vegetation and water resources quickly.

Droughts can be characterized based on their severity, duration, extent, and timing, which can be all measured by using various indicators. All of them rely on setting thresholds based on long term climate data. Such thresholds are then used to identify the onset and the end of a drought as well as the extent and the severity of the event.

Drought indicators are based on climatic variables or parameters used to describe drought conditions and include:

- Precipitation, e.g., rainfall and snow,
- Temperature,
- Streamflow, i.e., the volume of water that moves over a designated point in a fixed period of time,
- Groundwater and reservoir levels,
- Soil moisture and snowpack.

For example, precipitation is often monitored with the Palmer Drought Index or the Standardized Precipitation Index (SPI). There are also combined indicators or complex models that consider several biophysical variables, such as the National Land Data Assimilation System (NLDAS) or the Combined Drought Indicator in Europe (Copernicus European Drought Observatory). There are also indices used for water supply forecasting, such as the Surface Water Supply Index (SWSI), and indices which reflect impacts on vegetation, such as the Vegetation Health Index (VHI) and Vegetation Drought Response Index (VegDR).

The Handbook of Drought Indicators and Indices provides a compendium of the most used drought indicators/indices in drought-prone regions.

K.7.1 Early warning

At an international level, the Integrated Drought Management Programme (IDMP), co-sponsored by the WMO and the Global Water Partnership (GWP), has developed a comprehensive framework based on three pillars: drought monitoring and early warning, vulnerability and impact assessment, and drought mitigation, preparedness and response. IDMP has over 35 partner organisations, including the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Convention to Combat Desertification (UNCCD).

IDMP developed the National Drought Management Policy Guidelines, that include a 10-step process to assist countries in developing national drought plans and polices.

K.7.2 Rapid impact estimations

GDACS rapid impact estimation: Within 30min from source update (every 10 days): manual definition of alert level for humanitarian activation, this includes:

- Area mostly affected by drought,
- Risk of Drought Impacts for Agriculture (RDrI-Agri from the Copernicus Global Drought Observatory),
- Event map,
- Meteorological forecast map,
- Exposure estimates for affected countries.

Within GDACS, under the Satellite Mapping Coordination Systems (SMCS), satellite mapping information products also become available when the relative mapping services are activated.

K.7.3 Physical impact

Droughts can impact all socio-economic sectors that are dependent on water availability and the environment and are often interlinked with water scarcity issues and the consequences of unsustainable use of water resources. The impacts of drought can be multiple and persist over longer time scale compared to the ones associated to other hazards.

Drought can have a significant impact on the availability of water in the soil, surface water bodies, and groundwaters, both in terms of quantity and quality. It generally occurs gradually and affects large areas over an extended period. The initial phase of drought is usually marked by a departure from normal precipitation levels, which is referred to as meteorological drought. Subsequently, drought conditions continue to spread through the hydrological cycle, both spatially and temporally, which is known as hydrological drought.

As a result of the lack of water, various systems and sectors that rely on water are affected. These include agriculture, ecosystems, power generation, industry, river transportation, water supply, human and animal health, livelihood security, personal security, access to education, tourism, and recreation. Infrastructures and buildings located in certain soil types may also be affected due to the cracking and subsidence caused by the lack of water. The complete economic and financial consequences of droughts are difficult to quantify.

Regardless of the severity of drought, its impact greatly depends on the socio-economic context in which it occurs. The effects are determined by the exposure of people or things to the drought and the specific vulnerabilities of the affected area. Typical consequences may include:

- Decrease of vegetation productivity as a consequence of low soil moisture, affecting both agriculture and natural ecosystems.
- Shortage or lack of water from both surface and groundwaters.
- Water quality decreases, e.g., temperature, salinity, organic matter and turbidity, i.e., muddiness created by stirring up sediment or having foreign particles suspended.
- Presences of pathogens, algae blooms, oxygen content, and pollutants' concentration.
- Pest outbreaks in water-stressed ecosystems.
- Higher risk of wildfires by reducing fuel moisture content, enhancing its flammability, and increasing the amount of dead matter susceptible to fire, e.g., dead branches, foliage.
- Higher risk of floods as a result of decreasing soil absorbance and retention capability, thus increasing surface flows during intense precipitation events.

K.7.4 Direct impact on the population

As mentioned above, drought impacts depend heavily on the socio-economic contexts in which droughts occur. The effects of droughts are heavily influenced by the vulnerabilities of the population and what or who is exposed. Vulnerable populations are disproportionately affected by droughts, which are the most serious hazard to livestock and crops in nearly every part of the world. It's estimated that approximately 55 million people globally are affected by droughts every year.

Water scarcity impacts 40% of the world's population, and WHO estimates that as many as 700 million people are at risk of being displaced by 2030 due to drought.

In case of water supply shortages, a population will be exposed to discomfort and a regulated limitation in water use, or in extreme conditions will be displaced elsewhere.

The probability of health impacts resulting from drought can vary significantly, depending on the severity of the drought, the vulnerability of the population, existing health and sanitation infrastructure, and the availability of resources to mitigate the impacts. However, when drought leads to shortages of water and food in susceptible communities, it can have various effects on the health of the affected population, which may increase the risk of disease and death.

Droughts may adversely affect many economic sectors, e.g., agriculture, energy and industry, inland transportation, and tourism. An affected population may be subject to indirect impacts such as unemployment, an increase in the price of services, and mental health issues. Other acute and chronic effects, may include:

- Malnutrition due to the decreased availability of food.
- Micronutrient deficiency, such as iron deficiency anaemia.
- Increased risk of infectious diseases, such as cholera, diarrhoea, and pneumonia.
- Lack of safe water and sanitation.
- Lack of fodder and death of livestock can heavily affect pastoralist communities.
- Displacement, mass migration and rural abandonment.
- Economic downturns in any water-dependent sector.
- Conflicts over water resources and social unrest.
- Ecosystem collapse and biodiversity reduction.
- The increased risk of wildfires and dust storms may exacerbate respiratory and heart conditions.

K.7.5 Aggravating factors

- **Climate change -** an increase in global temperatures will lead to more frequent and severe droughts.
- **Heatwaves and high temperatures –** the heat greatly increases potential evapotranspiration, i.e., the sum of all processes by which water moves from the land surface to the atmosphere via evaporation and transpiration, which accelerates water depletion.
- Water scarcity – the unsustainable use of water resources, excessive abstraction and poor water management exacerbate drought effects.
- **Land degradation or unsustainable soil management** – the reduction of canopy cover, e.g., deforestation increases temperatures at ground level and reduces air moisture, and overexploitation alters the water cycle and may reduce water retention capability.
- **Urbanization –** increasing the amount of impervious surfaces and soil sealing prevents water from being absorbed into the ground and the local recharge of groundwater. Furthermore, the heat island effect and lack of vegetation exacerbate the loss of moisture.
- **Water pollution –** contamination of water sources can reduce the availability of clean water, worsening the consequences of a drought.

K.7.6 Typical needs

- Droughts severely limit access to clean water due to reduced precipitation and depleted water sources. Providing safe drinking water becomes a top priority to prevent dehydration and maintain hygiene. Temporary water supply issues may be addressed with water delivery by tankers, water purification, or through other technological temporary solutions.
- Crop failures and livestock losses may cause food shortages and malnutrition. Humanitarian efforts focus on providing food aid and nutritional support and implementing strategies for sustainable agriculture and food production. Crop failure may be covered by insurance schemes or government intervention in support of farmers and rural communities.

- Droughts may exacerbate health issues due to water scarcity, malnutrition, and displacement. Access to healthcare services, medicines, and disease prevention measures are crucial to address immediate health needs and prevent outbreaks.
- Many communities rely on livestock for food, income, and transportation. Providing veterinary services, supplementary feeding programs, and support for livestock management helps protect valuable assets and maintain livelihoods.
- Children and vulnerable populations are particularly at risk during droughts. Ensuring access to nutritional supplements, therapeutic feeding programs, and healthcare services targeting maternal and child health are essential to prevent long-term health consequences.
- Droughts often devastate livelihoods, particularly in agricultural-dependent communities. Supporting alternative income-generating activities, providing seeds for drought-resistant crops, and offering training in new skills help communities recover and build resilience.
- Displacement, as people move in search of water and food, may lead to the need for temporary shelter; improving infrastructure for water storage and distribution and building resilience against future droughts through better infrastructure planning are crucial aspects of humanitarian response.
- Droughts disrupt education and can cause psychological distress. Ensuring continued access to education for children, providing psychosocial support for affected individuals, and promoting community cohesion help mitigate the long-term impacts of droughts on mental well-being and social stability.
- Emergency situations also tend to exacerbate existing inequalities among the population and lead to a rise in human rights and protection concerns. Special considerations should be given to known protection risks in the context. See also **Chapter G.2** Centrality of protection and quality response. A breakdown of social structures and services can result in increased risks of exploitation, abuse, and neglect for vulnerable groups, and relief efforts must prioritize the unique needs of these groups to ensure their safety and well-being. Women and children often face heightened vulnerability and are disproportionately affected. Female-led households may have less access to resources, financial independence, and decision-making power, which complicates their ability to recover. Children are particularly susceptible to physical harm and psychological trauma. They may be orphaned, and displacement often disrupts their education and routine, leading to long-term challenges.

K.7.7 UNDAC mission

Given the usually slow-onset nature of droughts, UNDAC missions to droughts have been rare. However, due to climate change, one may expect droughts to appear more often, be more severe and have a faster evolution, e.g., flash droughts, and UNDAC may be mobilised to support an affected government with contingency planning, humanitarian and environmental assessments, and coordination of international assistance.

K.7.8 Safety concerns

Given the increased risk of wildfires and dust storms, appropriate clothing, facemasks, or gas masks may be needed as a contingency measure.

K.7.9 Security concerns

Normal precautions depending on context and the safety & security briefing from UNDSS.

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