



## RESILIENT COMMUNITIES THROUGH AWARENESS AND PREPAREDNESS AGAINST THE RISKS OF FIRE, FLOOD, AND LANDSLIDE

### CHAPTER 1. OCCURRENCE and IMPACT OF DISASTERS

**Prepared by:** Prof. Selcuk Toprak, Prof. Banu Cetin, Assoc. Prof. Cigdem Balcik,  
Assoc. Prof. Burak Aydogan, Tahsin Gormus, Oguz Dal

**GEBZE TECHNICAL UNIVERSITY**



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**OCCURRENCE AND IMPACT OF DISASTERS**

Disasters occur worldwide and can be categorized into different types based on their causes. Natural Disasters are events caused by natural forces and processes such as meteorology and geology. They can be very large in scale and have the potential to cause loss of life and property. Examples for natural disasters are floods, landslides, earthquakes, wild-fires, hurricanes and volcanic eruptions. Human-caused disasters are human originated disasters, as its name implies, and generally have regional impacts. Industrial accidents, transportation accidents, nuclear accidents, biological and environmental disasters can be an example for human-caused disasters. The occurrence of disasters varies depending on geographical location, climate, and human factors. Some regions are more prone to specific types of disasters due to their geographical features or climate patterns. Understanding the occurrence patterns and potential risks associated with different types of disasters is crucial for disaster preparedness, response, and mitigation efforts.

Every year, millions of individuals experience the impact of both natural and human-caused disasters. These disasters pose the risk of death and physical injury, and can lead to the loss of homes, possessions, and community infrastructure. Consequently, individuals affected by disasters have high risks of experiencing emotional and physical health problems. Stress reactions following a disaster exhibit similar patterns to those observed after any traumatic event. Disasters can trigger a wide range of mental and physical reactions, including responses to post-event problems and triggers associated with the traumatic experience.

Understanding the occurrence and impact of disasters is crucial for developing strategies to prevent, mitigate, and respond to such events. Governments, communities, and individuals play important roles in building resilience and minimizing the devastating effects of disasters.

**1.1. Occurrence and Impact of Flood**

### 1.1.1. Occurrence of Flood

A flood is typically defined as an overflow of water onto normally dry land, caused by excessive precipitation, dam failure, or other factors. Floods can be classified based on their magnitude, frequency, duration, and geographic extent. Understanding these classifications is crucial for assessing flood risks and designing appropriate mitigation measures. It explores natural causes such as intense rainfall, snowmelt, and riverine processes, as well as human-induced factors like deforestation, urbanization, and climate change. The interaction between these factors can amplify flood events and increase their frequency and severity. A comprehensive understanding of the causes enables scientists and policymakers to develop effective strategies to minimize flood impacts.

Floods are natural hydrological disasters that have significant impacts on human lives, infrastructure, and the environment. Understanding the occurrence of floods is crucial for enhancing preparedness, minimizing damage, and building resilience in vulnerable regions. Floods result from a combination of natural and human-induced factors. Firstly, intense or prolonged precipitation events play a significant role. Heavy rainfall, often associated with convective storms or tropical cyclones, can overwhelm drainage systems and cause rivers to breach their banks. Moreover, snowmelt during the spring or sudden ice jams in rivers can lead to excessive runoff and subsequent flooding. Human activities also contribute to floods, such as deforestation, urbanization, and improper land use practices that alter natural drainage patterns (Middelmann-Fernandes, 2009). The detailed classification of floods is given in Table 1.1.

The frequency and severity of floods can vary depending on geographical location, climate patterns, and local infrastructure. Some regions are more prone to flooding than others due to factors such as proximity to rivers or coastal areas, topography, or poor drainage systems. It's important to note that while floods are relatively common and occur in different parts of the world, the specific occurrence of floods in any given area can vary significantly. Additionally, the effects of climate change, such as rising sea levels and increased precipitation in certain regions, can potentially influence the occurrence and intensity of floods in the future. General causes of floods can be classified as follows:

- run of more than convenience capacity
- deterioration of drainage channels
- drainage congestion

- deforestation
- rise in sea level due to the wind
- tidal waves/tidal effect
- global climate change
- impact of embankment constructed elsewhere.

Table 1.1. Classification of floods.

Flood Classification			
1. Floods by Type			
A. River Floods 1. Upstream and flash floods a) Low glide speed b) Short duration, heavy rains c) Too much loss of life 2. Downstream Floods a) The duration is long b) High precipitation during this period		B. Coastal Floods (Ocean, Sea, Lake etc.) From high tides or storm surges	
2. Flood due to rainfall			
3. Floods due to snow-glacial melting			
4. Floods occur according to time			
A) Summer Flood Because of heavy rains in summer	B) Winter Flood		C) Spring Flood As a result of snow-melt
5. Floods according to their duration			
A) Flash floods Floods occur within 6 hours.		B) Long-term floods Floods that last a week or more.	
6. According to flood formation location			
Stream and river flood	Mountain area flood	City flood	Coastal flood
7. According to flood causes			
A. Natural Factors 1. Physical Structure of the land 2. The amount of saturation of the land with water-stream flow rate		B. Human Factors 1. Crooked city structure 2. Lack of afforestation and trees cut off 3. Embankment / dam, etc. drawn to the riverbed. like demolition and global warming	

## A) River Flood

Rainfall serves as the primary catalyst for flood occurrence; however, numerous additional factors play a role (Fig. 1.1). The extent to which rainwater reaches waterways within a catchment is contingent upon the catchment's attributes, notably its size, shape, and land usage. A portion of the precipitation is absorbed by the soil and vegetation, while the remaining volume enters waterways as runoff. Various characteristics of the river, including its dimensions, configuration, vegetation cover, and the presence of structures within and near the waterway, collectively influence the water level within the watercourse.

Floods occur when the volume of water surpasses the drainage capacity of catchments, drains, creeks, and rivers. Although rainfall initiates this process, numerous factors come into play. The amount of rainwater transformed into flow within rivers and waterways depends on catchment characteristics. A portion of the rainfall is captured by the soil and vegetation. Generally, areas experiencing higher rainfall intensities and larger rainfall coverage allow for less water to seep into the ground or be stored on the surface. **The presence of vegetation** contributes to increased rainwater capture, reducing the water available for surface flow. Natural and artificial storages, such as farm dams and rainwater tanks, also decrease runoff. **Soil types, land use, and pre-existing weather conditions** influence the infiltration of rainfall into the soil and consequently the amount of flow generated.

Factors like impervious surfaces (e.g., roofs, roads) hinder water absorption, reducing infiltration and increasing surface runoff. Once water enters the waterways, various factors determine the amount and speed of downstream flow. Larger catchments tend to yield higher streamflow during prolonged and widespread rainfall. Steeper catchment slopes facilitate faster runoff. **The roughness of the terrain**, including vegetation, fences, and structures, influences water flow velocity, often resulting in lower flood levels downstream. Natural features like swamps, ponds, and lakes act as temporary floodwater storage, releasing it gradually. **Artificial structures**, such as dams and detention basins, also store water, reducing downstream flow peaks and extending flood event durations. However, all these structures have limited capacity, and there is a threshold for the volume of catchment flow they can store.



Figure 1.1. Conceptual diagram of river flood ([www.chiefscientist.qld.gov.au](http://www.chiefscientist.qld.gov.au)).

The carrying capacity of drains, creeks, and rivers within a catchment is influenced by various factors:

- ✓ **River Size and Characteristics:** The size, straightness, and smoothness of a river or creek directly impact its capacity to transport water, reducing the likelihood of flooding. Any factor that diminishes this capacity, such as the presence of structures in the channel, encroachment from development, or sediment accumulation, contributes to increased flood risks.
- ✓ **Vegetation in and around Waterways:** The presence of plants within a river or along its banks slows down the water flow. Slower water movement results in higher water levels and increased floodplain inundation. This, in turn, can mitigate downstream flood levels and flows. Vegetation also serves to reinforce riverbanks, preventing erosion and facilitating sediment deposition.
- ✓ **Characteristics of the Adjacent Floodplain:** When a river breaches its banks, the maximum flood level attained greatly depends on the nature of the surrounding floodplain. Wide and flat floodplains have a greater capacity to store floodwater, leading to

slower-moving floods. Any modifications made to floodplains, such as vegetation clearance or the construction of embankments, can alter the natural drainage patterns and processes on river floodplains. Basic components of a flood hazard area are illustrated in Fig. 1.2.

- ✓ **Impact of Structures:** Structures installed in creeks or waterways, such as culverts in urban drainage systems or bridges across rivers, diminish the water-carrying capacity of these water bodies and can contribute to flooding. Additionally, debris accumulation on these structures can exacerbate the problem.
- ✓ **Influence of Levees and Embankments:** Levees constructed along waterways are designed to protect areas behind them from floods up to a specific level. However, they restrict flood flows, potentially leading to higher upstream flood levels. Road and railway embankments with inadequate cross-drainage capacity, such as insufficient culverts, can block portions of the floodplain, producing similar effects. Once levees or embankments are overtopped or breached, the spreading pattern of floodwaters across the floodplain can be significantly altered, often resulting in severe flooding.
- ✓ **Downstream Water Levels:** The capacity of waterways can also be influenced by the water level in the ocean or lake into which they flow. For instance, during a king tide or storm surge, the release of water from a river into the ocean can be impeded. Similarly, at the confluence of creeks with rivers, backwater effects caused by river flooding can extend upstream in the creeks for a considerable distance.

Overall, these factors collectively impact the capacity of waterways to carry flows, influencing the occurrence and severity of floods within a catchment.

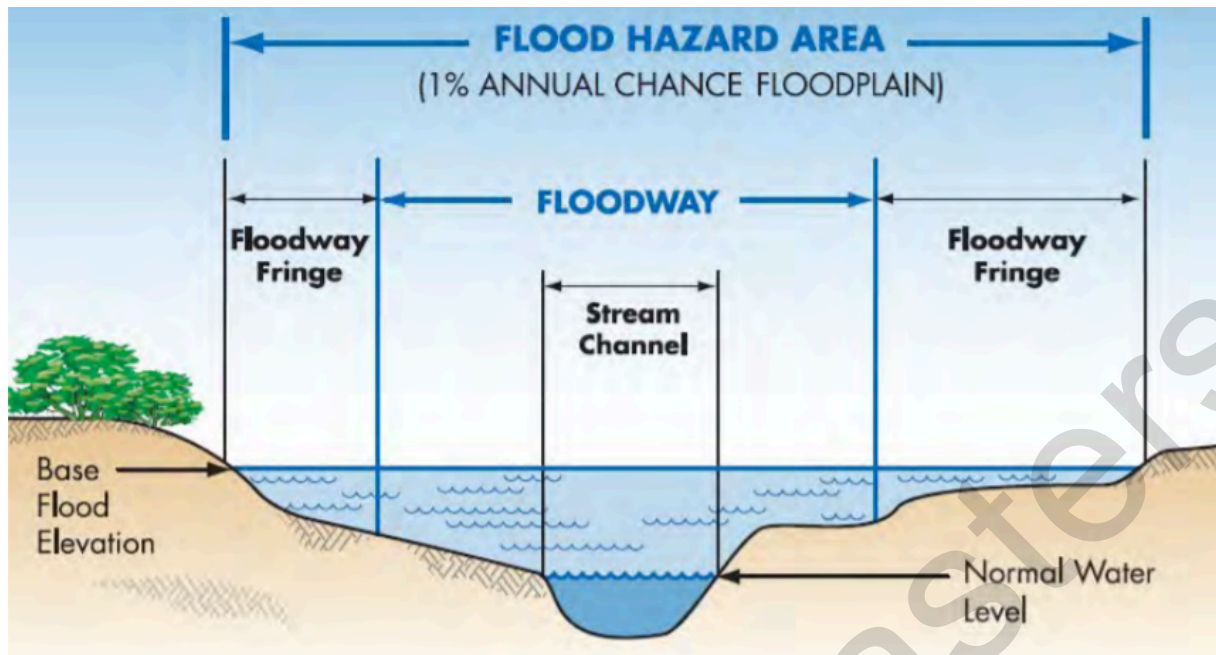


Figure 1.2. Basic components and terminology of flood hazard areas (<https://www.upperdarby.org/FloodplainManagement-1>).

## B) Coastal Flood

Coastal flooding refers to the occurrence of flooding in areas that are typically dry and located at a lower elevation, as they become inundated with seawater. This phenomenon arises due to a rise in sea level, causing the water to overflow onto the land. Coastal flooding can transpire in the following ways:

- ✓ **Direct flooding:** This transpires when the land lies at a lower altitude than the sea level, lacking natural obstructions such as dunes to impede the waves from advancing onto the land.
- ✓ **Water surpassing a barrier:** This transpires during storms or high tides when the water level exceeds the height of a barrier. Consequently, the water spills over the barrier, resulting in flooding on the opposite side. Barriers can be either natural, like dunes, or artificial, such as dams.
- ✓ **Water breaching a barrier:** This transpires when water, typically in the form of powerful waves, forcefully breaches a barrier. This breach can either cause the barrier to deteriorate or destroy it. This barrier can be of natural or artificial origin.

There are numerous factors that can contribute to flooding occurring along or near the coastline. The primary causes encompass:

**Elevation of the land relative to sea level:** Coastal flooding poses a significant threat to low-lying areas along the coast, as the ingress of seawater can readily extend inland. The mega-deltas of Asia serve as a prime illustration of regions susceptible to coastal flooding.

**Erosion and subsidence:** Erosion refers to the process by which materials, such as earth or sand, are gradually worn away and transported to other locations through natural forces like waves or wind. This displacement of materials from their original position can lead to the weakening or complete removal of the affected area. A notable example of erosion can be observed in Holderness, located in Yorkshire, England. The relentless battering of waves, storms, and tidal surges continually erodes the coastline of Holderness. Approximately 2 meters of land erodes from Holderness each year, steadily diminishing the size of the coastal stretch. This erosion has resulted in the loss of properties, farmland, damage to infrastructure, and poses a threat to both tourism and coastal protection.

Subsidence occurs when underground substances shift, causing the ground to sink. This can be a consequence of natural factors like earthquakes or erosion, as well as human activities such as mining mineral resources or extracting natural gas. Coastlines situated at low elevations are naturally susceptible to subsidence due to the settling and compaction of recently deposited sediment. Typically, this subsidence is balanced by ongoing sediment deposition. However, human activities can induce local subsidence through practices such as draining waterlogged sediment/soil in agriculture, as seen in the Fens of East Anglia. The weight of coastal towns and cities, along with the built environment, can also compress the underlying sediment, resulting in subsidence, such as Venice. Land reclamation projects, like the Netherlands' IJsselmeer polders, are also prone to subsidence due to water extraction through crop evapotranspiration.

Signs of subsidence in buildings include:

- Diagonal cracks appearing in walls.
- Uneven floor surfaces as the floor sinks or shifts.
- Difficulty in opening or closing doors and windows, or misalignment of these structures.
- Cracks developing at the junction of extensions with the main building, indicating potential separation between the two structures.

**Removal of vegetation:** Coastal vegetation, which includes trees and other plants, plays a crucial role in regulating the movement of rainfall. It acts as a barrier, intercepting rainfall and slowing down its flow. Some of the intercepted water is stored within the vegetation, while the rest evaporates back into the atmosphere. Furthermore, the vegetation facilitates the absorption of water by the soil, allowing for greater infiltration and reducing surface run-off.

When coastal vegetation is removed, the capacity for infiltration and interception is diminished, resulting in increased surface run-off. This heightened run-off poses a greater risk of flooding as more water reaches the river channel, potentially overwhelming its capacity. Moreover, coastal vegetation serves to stabilize existing sediment and capture new sediment, effectively elevating the land's height above sea level. Additionally, it absorbs the energy of incoming waves, mitigating wave impact and erosion, and decreases the distance that waves can travel onshore before their power dissipates. For instance, a 100-meter belt of mangrove forest is estimated to reduce wave height by 40%. Similarly, a 1-kilometer belt of mangrove forest can significantly reduce the magnitude of a storm surge by 0.5 meters.

**Storm surges:** The occurrence of storm surges is a significant cause of coastal flooding. Storm surges are temporary elevations in sea levels resulting from events like tsunamis and cyclones. A storm surge is measured by the water level exceeding the normal tidal level, disregarding the presence of waves. Multiple meteorological factors contribute to the formation and intensity of a storm surge:

- High-speed winds propel water towards the coastline over a considerable distance, known as fetch.
- The shallowness and alignment of the body of water play a role in amplifying the effects of a storm surge.
- The timing of tides can influence the impact of a storm surge, with high tides exacerbating the flooding.
- A decrease in atmospheric pressure can further elevate the water level, intensifying the storm surge.

### **Effects of climate change on coastal flooding**

It is known that global warming is causing a rise in sea levels, but it is important to understand the implications of this rise in relation to coastal flooding and erosion. It should be noted that depressions and cyclones can occur independently of global warming and sea level

increases. However, there is substantial evidence suggesting that global warming will amplify the risks faced by coastal regions. According to a summary by the Intergovernmental Panel on Climate Change (IPCC) in 2014, the following key points were highlighted:

- **Sea levels:** There is a high level of confidence that sea levels will rise between 28 and 98 centimeters by the year 2100, with the most probable estimate being an increase of 55 centimeters (Fig. 1.3).
- **Delta flooding:** There is a high level of confidence that the world's significant deltas, which are already at risk of coastal flooding, are likely to face a 50 percent increase in this risk.
- **Wind and waves:** There is evidence with a moderate level of confidence indicating increased wind speeds and a greater occurrence of large waves.
- **Coastal erosion:** There is a moderate level of confidence that coastal erosion will intensify due to the combined effects of changes in weather patterns and rising sea levels.
- **Tropical cyclones:** There is a low level of confidence regarding any notable changes in the frequency of tropical cyclones. However, it is likely that more severe storms will occur.
- **Storm surges:** There is a low level of confidence indicating that storm surges associated with depressions are becoming more common.

In summary, while the precise impacts may vary, there are indicators that global warming and rising sea levels will heighten the risks faced by coastal areas, including increased flooding, erosion, stronger wind speeds, and larger waves.

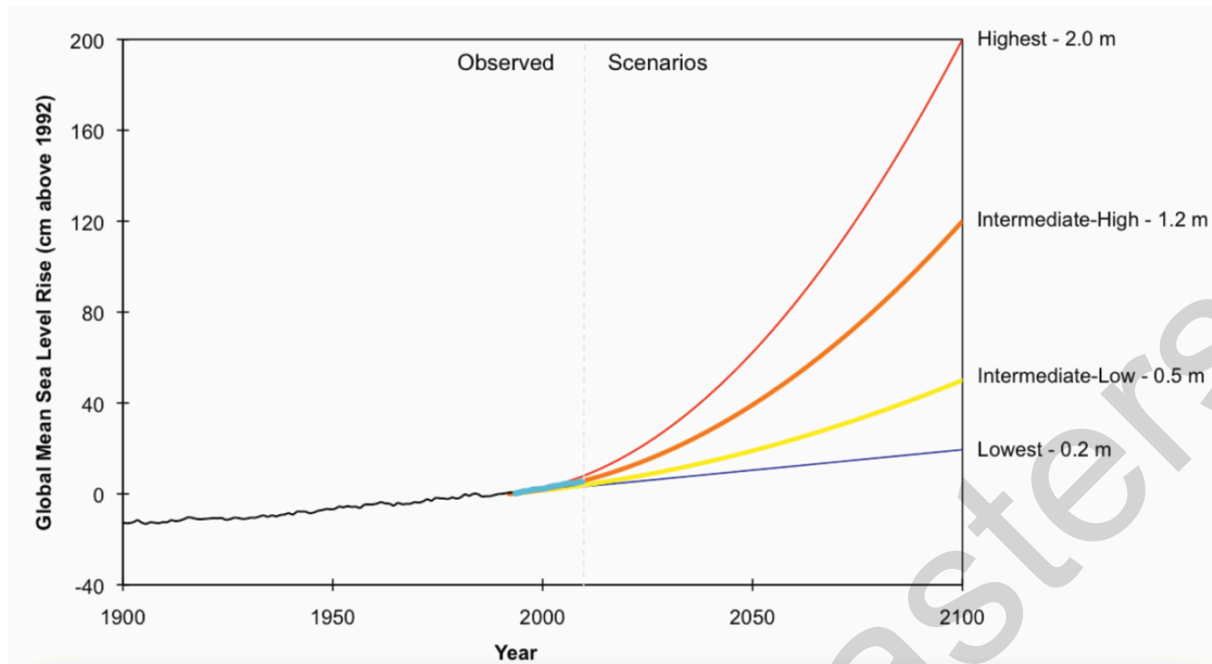


Figure 1.3. Projections of global mean sea level rise (Parris et al., 2012).

### C) Flash Flood

When an area receives a greater amount of rainfall than the ground can absorb, or when the precipitation falls on surfaces such as concrete and asphalt that impede absorption, the excess water has limited place to go, leading to a swift rise in water levels. If the soil is already saturated from recent rainfall, it becomes incapable of absorbing additional water. Conversely, during a drought, the soil may be too dry and compacted to effectively absorb the precipitation. Flash floods are frequently observed in desert landscapes following heavy rainfalls, as well as in areas where shallow soil depth rests above solid bedrock, restricting the soil's ability to absorb rainwater.

Due to the natural flow of water downhill, rainfall seeks the lowest point along its potential path. In urban areas, this often occurs as flooding in streets, parking lots, and basements located in low-lying zones. In rural regions with steep terrain, flash flooding can transform creeks and rivers into raging torrents. Despite efforts by weather forecasters and emergency personnel to issue warnings and prepare communities, flash floods often catch people off guard. These events have the potential to wash away vehicles and even displace buildings from their foundations.

If a levee or dam is overtopped or experiences damage or compromise, it can also result in catastrophic flash flooding. Such situations involve a sudden and substantial release of water, often occurring with minimal warning. The rapid surge of water can submerge entire towns, presenting a severe threat to the lives of residents.

A significant illustration of this occurred during the devastating Hurricane Katrina in 2005. The storm caused numerous breaches in the levee system across New Orleans, leading to an unprecedented and historic flood. As a result, people sought refuge on their rooftops as the floodwaters rose, resulting in the tragic loss of hundreds of lives.

Some real case studies of different flood types are shown in Fig. 1.4.



Figure 1.4. Examples of real cases of floods a) and f) flash floods, b) and e) coastal floods, c) and d) river floods.

### 1.1.2. Impact of Flood

Floods have wide-ranging effects on individuals and communities, resulting in social, economic, and environmental impacts (Langill and Abizaid, 2019). The impact of floods, whether positive or negative (Table 1.2), can differ significantly based on factors such as location, duration, depth, and speed of the flood, as well as the vulnerability and significance of the affected natural and built environments. Several key factors that make people vulnerable to floods:

- Poverty and disparities in wealth distribution.
- Unplanned and swift urban growth.
- Climate change and fluctuations in weather patterns.
- Inadequate management of natural resources.
- Insufficient consideration of disaster risks.
- Limited access to technology.
- Absence of environmental regulations.
- Unsustainable utilization of natural resources.
- Outbreaks of pandemics and epidemics.
- Socio-economic elements such as ethnicity, religion, gender, age, and health status.

Table 1.2. Positive and negative effects of floods.

Impact of Floods	
Positive Effects	Negative Effects
Many rural areas across the globe rely on the yearly floods for the sustenance of their communities. Ex: encompass riverine settlements situated in the Amazon rainforest and communities in Peru and Colombia. Because of this, floods play a crucial role in enabling transportation, facilitating the migration of fish, and enriching the fertility of the soil.	Floods, which are the most costly and dangerous disasters, inflict adverse consequences on individuals, communities, properties, and the environment, causing significant distress and damage.
1. Making the land fertile,	1. Damage to build infrastructure
2. Adding nutrients to the sea	2. Economic losses
3. Dislodging accumulated debris	3. Loss of lives and social disruption
4. Supplying sediment to deltas	4. Erosion
5. Recharging groundwater levels	5. Spread diseases and contamination
6. Balancing the health of wetlands	6. Algal blooms

#### 1.1.2.1. Environmental impacts

- ✓ **Sedimentation and erosion:** Floodwater can modify the physical landscape through various means, such as the erosion and collapse of riverbanks. As floodwater carries away

eroded materials, it also suspends sediment in the water, resulting in degraded water quality and the potential for harmful algal blooms. Over time, this suspended sediment settles out of the water, a process known as sedimentation. Unfortunately, sedimentation can lead to the obstruction of riverbeds and streams, suffocating aquatic organisms and causing the destruction of habitats. Ecosystems that are already degraded or extensively altered experience a heightened negative impact from erosion and sedimentation.

✓ **Transport of contamination:** Floodwater can be polluted with various pollutants, including agricultural pesticides, industrial chemicals, debris, and sewage. When contaminated floodwater discharge to the ocean, it can have detrimental effects on water quality and disrupt sensitive ecosystems, such as coral reefs. A notable example occurred in February 2019 when marine biologists expressed concerns about the well-being of the Great Barrier Reef, located off the coast of Queensland, Australia. The reef faced potential harm due to being inundated with polluted floodwater.

During a flood, along with several susceptibilities, problems with water supply, sanitation, and health become more serious. Flooding can damage water and sanitation systems, making it easier for waterborne diseases to spread and causing significant health issues. Ensuring access to clean water and proper sanitation facilities is essential to prevent the outbreak of illnesses. Emergency response teams should prioritize water purification, distribution, and the construction of temporary sanitation facilities to safeguard public health.

Water serves as both a fundamental necessity for life and a crucial element in maintaining proper sanitation and personal hygiene practices. Even when there are sufficient water supply and sanitation facilities, their effective management becomes imperative, especially in flood situations. Recognizing this, some rural communities with both means and awareness have implemented the following measures to safeguard their water sources during floods (Shimi et al., 2010):

- Tube Well (a pipe or tube bored into an underground aquifer) Measures:
  - Elevating tube wells on raised bases to prevent submersion during floods.
  - Cementing the base to prevent contaminated floodwater from entering the tube well.
  - Increasing the height of tube wells using pipes to prevent inundation.
- Storing Drinking Water:
  - Storing clean drinking water in containers to ensure a safe supply during floods.
- Disinfection of Water:

- Using water-purifying pills to maintain the safety of tube well water.
- Boiling floodwater before use to eliminate contaminants.
- Treating floodwater with alum before use as an additional purification measure.

✓ **Spreading diseases:** The spread of diseases is a significant consequence of floods, with floods being the primary cause of infectious disease outbreaks related to weather. Flooding events heighten the risk of waterborne diseases, including hepatitis A and cholera. As floodwater recedes, stagnant pools form, creating ideal breeding grounds for mosquitoes that can transmit malaria and various other diseases. Furthermore, flood events contribute to an upsurge in certain zoonotic diseases, such as leptospirosis.

✓ **Harmful effect on wildlife:** The impact of flooding on wildlife is predominantly negative, leading to drowning, increased disease transmission, and the destruction of habitats. A notable incident occurred in 2012 when extensive flooding engulfed Kaziranga National Park in the Indian state of Assam, resulting in the death of numerous animals, including vulnerable one-horned rhinos (*Rhinoceros unicornis*). Even aquatic life is not spared from the detrimental effects of unpredictable floods, as fish can be displaced and their nests destroyed, disrupting their natural reproductive processes.

#### 1.1.2.2. Social impacts

Social impacts refer to the effects of events on the well-being of people.

✓ **The loss of lives and property** is a direct consequence of flooding. The immediate impacts encompass the tragic loss of human life, damage to property, destruction of crops, loss of livestock, non-functioning of essential infrastructure facilities, and a decline in overall health conditions due to waterborne diseases. It is known that flash floods, characterized by their sudden onset and minimal warning time, tend to result in a higher number of fatalities compared to slow-rising riverine floods.

✓ **The psychosocial consequences** experienced by flood victims and their families can have enduring and profound effects. The loss of loved ones, particularly for children, can create deep emotional wounds. The displacement from one's home, the loss of property and livelihoods, and the disruption of business and social activities can lead to ongoing stress.

Overcoming these losses can be an overwhelming burden, resulting in long-lasting psychological impacts.

- ✓ **Mass migration** can be triggered by repeated flooding, which leads to the loss of livelihoods, reduced production, and prolonged economic suffering. These circumstances often force people to leave their homes and seek refuge elsewhere. In many cases, migration occurs towards developed urban areas, contributing to overcrowding in cities. As a result, these migrants add to the population of the urban poor and often end up residing in vulnerable areas within cities that are prone to floods or other risks. The selective out-migration of the workforce can also give rise to intricate social issues and challenges.
- ✓ **Political implications:** A failure to effectively respond to relief operations during significant flood events can result in public dissatisfaction or a loss of trust in the authorities, as well as at the state and national government levels. The absence of adequate development in flood-prone regions may contribute to social inequality and, in extreme cases, even spark social unrest, posing a threat to peace and stability within the region.

#### 1.1.2.3. Economic impacts

- ✓ **The loss of livelihoods** is a significant consequence of flooding. As vital communication networks and infrastructure, including power plants, roads, and bridges, suffer damage and disruption, economic activities grind to a halt. This disruption extends beyond the duration of the flood, causing dislocation and the breakdown of daily life. Additionally, the direct impact on productive assets, whether in agriculture or industry, can impede regular operations and result in the loss of livelihoods. Furthermore, the ripple effects of these livelihood losses can extend to business and commercial activities, even in neighboring areas that were not directly affected by the flood.
- ✓ **The decreased ability to purchase and produce goods** and services is another consequence of infrastructure damage. This damage not only has immediate effects but also results in long-term impacts such as disruptions to essential services like clean water, electricity, transportation, communication, education, and healthcare. The loss of livelihoods, reduced purchasing power, and decreased land value in flood-prone areas

further exacerbate the vulnerability of communities residing in those regions. Additionally, the additional expenses associated with rehabilitation, relocating affected individuals, and removing property from flood-affected areas can divert the capital that would otherwise be used for maintaining production.

- ✓ **Economic growth and development** can be impeded by floods. The substantial expenses associated with relief and recovery efforts can negatively affect investments in crucial infrastructure and other developmental initiatives within the affected area. In some cases, the fragile economy of the region may be severely crippled. The recurrent nature of flooding in a particular region can discourage long-term investments from both the government and the private sector. The combination of lost livelihoods, skilled labor migration, and inflation can further impact the region's economic growth adversely. Additionally, the loss of resources can result in higher costs of goods and services, thereby delaying the implementation of development programs (Bureau of Transport Economics, 2001).

Table 1.3. The catastrophic historical floods around the world.

Name and date	Reason and location	Consequences
Great Drowning of Men or Saint Marcellus's flood 13.01.1362	intense extratropical cyclone British Isles, Netherlands, Northern Germany and Denmark	25,000 people died
the Johnstown Flood or the Great Flood of 1889 31.05.1889	Following intense rainfall, the dam broke, releasing a massive 14.55 million m <sup>3</sup> of water. Johnstown, Pennsylvania, USA	Damage worth \$17 million killed 2,209 people
1887 Yellow River Flood 28.09. 1887	Qing China	Killed at least 930,000 people
The Yangtze-Huai River floods June-August 1931	Wuhan, Nanjing, and other large Chinese cities	Around 140,000 people drowned and 2 million died during the flood, either from drowning or lack of food. In the following year, a cholera pandemic

		caused 31,974 deaths and 100,666 cases.
The Banqiao Dam disaster August 1975	Dam break Henan, China	Death toll of ü 26,000-240,000; 5-6.8 million homes to fall down; 0.15 million people affected and 30 cities and counties over 12,000 km <sup>2</sup> flooded.
North Sea Flood 1953	A storm tide the sea flooded land up to 18.4 feet above mean sea level. Netherlands, northwest Belgium, England, and Scotland	The damage cost was £50 million in 1953 (£1.2 billion in 2013). Over 30,000 people evacuated, 24,000 properties were damaged, and more than 990 miles of coastline and 160,000 acres were affected due to over 1,200 seawall breaches.

Whether caused by intense rainfall, storm surges, or the failure of dams, floods have frequently resulted in the loss of thousands of lives and the devastation of entire cities. In certain instances, these floods have even brought about permanent alterations to the geographical landscape of the planet. Table 1.3 shows detailed information (date, location, cause and consequences) of selected largest historical floods worldwide.

## 1.2. Occurrence and Impact of Landslide

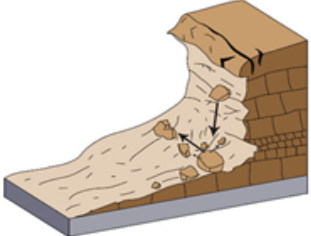
### 1.2.1. Occurrence of Landslide

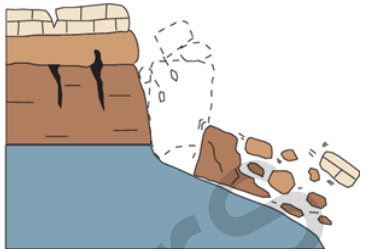
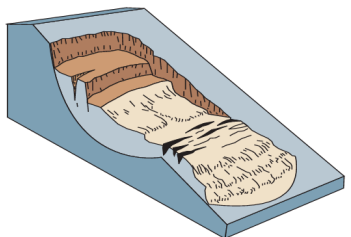
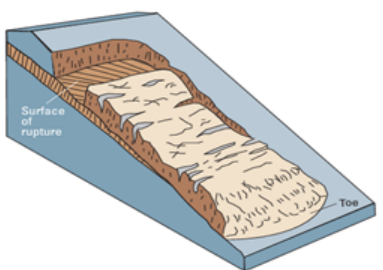
Landslides, also called mass movement or slope failure, are natural occurrences in which a mass of soil or rock on a slope moves downward as a cohesive unit or fragment due to various factors such as rainfall, earthquakes, or other triggers. They are one of the most lethal and destructive natural disasters. While gravity remains the principal force driving landslides, the stability of a slope is subject to the influence of multiple factors. These factors include the type and strength of the materials involved, lithological structure, hydrogeology, slope angle, seismic activity, and meteorological and environmental conditions including marine processes. Understanding these conditions plays a vital role in anticipating potential locations, types, and extents of potential failures.

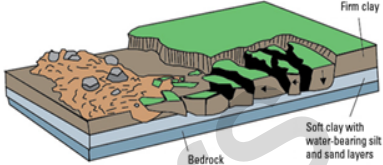
According to a report by the World Health Organization (WHO), landslides affected an estimated 4.8 million people, resulting in over 18,000 deaths between 1998 and 2017. The predictable effects of climate change and rising temperatures are expected to trigger more

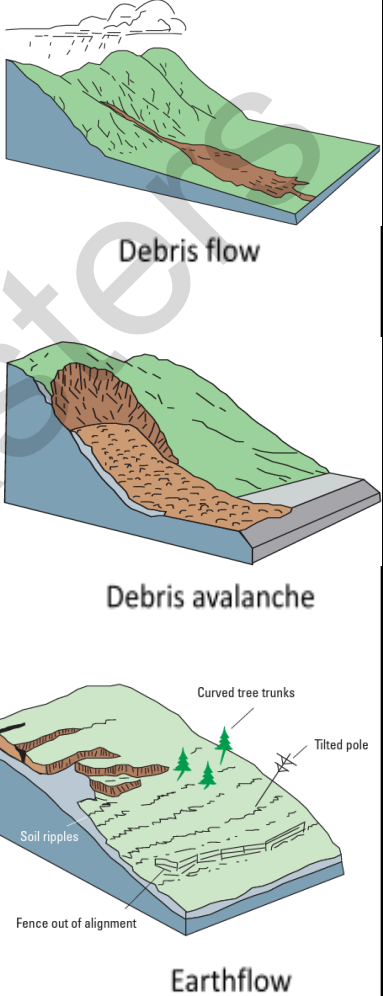
landslides, particularly in mountainous regions with snow and ice. As permafrost melts, rocky slopes become increasingly unstable, thereby increasing the risk of landslides. Landslides can occur in conjunction with heavy rainfall, drought, earthquakes, or volcanic eruptions. Certain areas are particularly susceptible to landslides, such as steep terrain, including the bottom of canyons, land that has been previously ravaged by wildfires and/or altered by human activities such as deforestation or construction, channels along streams or rivers, areas where surface runoff is directed, or where the land is heavily saturated. Landslides can be classified into various types based on the movement pattern and the materials involved. The detailed classification of landslides is given in Table 1.4, along with their occurrence, triggering mechanisms and schematic view of each landslide type.

Table 1.4. Classification of Landslide (Hung et al., 2014; Turner, 2018).

Types of Landslide	Occurrence and relative size/range	Triggering mechanism	Schematic view
<b>Falls</b>	Prevalent in steep or vertical slopes globally, also in coastal regions and rocky riverbanks. The size of material involved in a landslide can range greatly, from small rocks or soil clumps to large blocks measuring thousands of cubic meters.	Undermining of slope by natural phenomena like streams, rivers, and differential weathering (such as the freeze/thaw cycle), as well as human activities such as excavation for road construction or maintenance. Additionally, earthquakes and strong vibrations can also contribute to the destabilization of slopes.	

<b>Topple</b>		Observed worldwide and are frequently found in volcanic regions characterized by columnar jointing. They also commonly occur along the steep banks of streams and rivers.	can be triggered by various factors, including the gravitational force exerted by material located uphill from the displaced mass. They can also be influenced by the presence of water or ice within cracks in the mass. Other factors such as vibrations, undercutting, differential weathering, excavation, or stream erosion can also contribute to the occurrence of topples.	
<b>Slides</b>	<b>Rotational</b>	the most common type of landslide in "fill" materials due to their occurrence in homogeneous materials. These are typically linked to slopes ranging from approximately 20 to 40 degrees.	Intense rainfall, rapid snowmelt, and other factors like changes in river and groundwater levels can saturate slopes and contribute to landslides. These events can also be triggered by earthquakes.	
	<b>Translational</b>	One of the most widespread types of landslides globally. They are typically shallower than rotational slides. The surface of rupture has a distance-to-length ratio of less than 0.1 and can vary in size from small residential failures to large regional landslides spanning kilometres.	Intense rainfall, rising groundwater levels from rainfall, snowmelt, flooding, irrigation, or water leakage, as well as human-related factors like undercutting, can trigger this type of landslide. They can also be induced by earthquakes.	

<p><b>Spreads</b></p>	<p>Observed globally and typically happen in regions with soils prone to liquefaction. While they are commonly associated with seismic activity, their occurrence is not limited to such areas. Initially, the affected area may be small with a few cracks, but these cracks can rapidly expand, impacting areas hundreds of meters wide.</p>	<p>Triggers for destabilizing the weak layer include liquefaction caused by earthquake shaking, overloading of the ground above an unstable slope due to natural or human factors, saturation of the underlying weaker layer from precipitation, snowmelt, or groundwater changes, liquefaction of sensitive marine clay following erosion at the base of a riverbank or slope, and plastic deformation of unstable material at depth (such as salt).</p>	
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<p><b>Flows</b></p>	<p>Debris flows are widespread and often found in steep gullies and canyons. They can be exacerbated when occurring on slopes or in gullies stripped of vegetation due to wildfires or logging. Volcanic regions with weak soil commonly experience such flows. They vary in thickness and can be thin and watery or thick with sediment and debris, typically staying within the dimensions of the steep gullies that guide their movement. The flows are generally shallow and have a long and narrow runout, sometimes extending for kilometres in steep terrain.</p>	<p>Debris flows often result from intense surface-water flow caused by heavy precipitation or rapid snowmelt. This flow erodes and mobilizes loose soil or rock on steep slopes. Additionally, debris flows can originate from other types of landslides on saturated steep slopes, involving a significant amount of silt and sand-sized material.</p>	
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Examples of real cases of landslides are given in Fig. 1.5, for different landslide types including spread, fall and topple landslide.

The primary trigger for landslides is the saturation of slopes by water. This saturation can occur by different factors such as heavy rainfall, snowmelt, fluctuations in groundwater levels, and changes in water levels along coastlines, earth dams, and the banks of lakes, reservoirs, canals, and rivers. Landslides and flooding are interrelated, as they are influenced by precipitation, runoff, and the saturation of the ground by water. Furthermore, debris flows and mudflows typically transpire in small, steep stream channels, which are often mistaken for floods. In reality, these two phenomena frequently occur concurrently in the same region (Froude and Petley, 2018).

Landslides can induce flooding by forming landslide dams that obstruct the valleys and stream channels, leading to the accumulation of substantial amounts of water. This, in turn, results in backwater flooding, and if the dam fails, subsequent downstream flooding occurs. Additionally, solid debris from landslides can increase the volume and density of normal streamflow, causing blockages and diversions that contribute to flood conditions or localized erosion. Landslides can also lead to the overtopping of reservoirs and/or reduced storage capacity, exacerbating flood risks.



Figure 1.5. Examples of real cases of landslides a) spread b) debris flow c) earthflow d) rockfall e) topple.

A historical record of moderate seismic activity exists in various mountainous regions that are prone to landslides. The occurrence of earthquakes in these steep areas significantly increases the probability of landslides, either through direct ground shaking or soil dilation induced by shaking, which facilitates rapid water infiltration. Furthermore, ground shaking can loosen rocks, leading to widespread rockfall. On a global scale, landslides caused by earthquakes have a high fatality rate and inflict significant damage on structures. Landslides triggered by volcanic activity represent some of the most catastrophic events. In such cases, the interaction between volcanic lava and snow can lead to rapid melting of snow, resulting in a torrential mixture of rocks, soil, ash, and water. This destructive mixture gains tremendous momentum as it hurtles down the steep slopes of volcanoes, devastating everything in its path. Known as volcanic debris flows or lahars, these flows can travel significant distances beyond the

volcano's flanks and cause structural damage in flat areas surrounding the volcanic region. The causes of landslides are summarized in Table 1.5.

Table 1.5. Causes of landslides (Highland and Bobrowsky, 2008).

Causes	
Geological factors	<ul style="list-style-type: none"> <li>- Presence of weak or sensitive materials</li> <li>- Weathering of materials</li> <li>- Formation of sheared, jointed, or fissured materials</li> <li>- Adverse orientation of discontinuities such as bedding, schistosity, faults, unconformities, contacts, etc.</li> <li>- Contrast in permeability and/or stiffness of different materials</li> </ul>
Morphological factors	<ul style="list-style-type: none"> <li>- Tectonic or volcanic uplift</li> <li>- Rebound of glacial activity</li> <li>- Erosion of slopes by fluvial, wave, or glacial processes, either at the base or on the sides</li> <li>- Subterranean erosion, including solution or piping</li> <li>- Loading of slopes or their crests due to deposition</li> <li>- Removal of vegetation through fire or drought</li> <li>- Thawing processes</li> <li>- Weathering caused by freeze-and-thaw cycles</li> <li>- Weathering caused by shrink-and-swell processes</li> </ul>
Human activities	<ul style="list-style-type: none"> <li>- Excavation of slopes or their bases</li> <li>- Loading of slopes or their crests</li> <li>- Drawdown of reservoirs</li> <li>- Deforestation</li> <li>- Irrigation</li> <li>- Mining operations</li> <li>- Artificial vibrations</li> <li>- Water leakage from utilities</li> </ul>

## **1.2.2. Impact of Landslide**

### **1.2.2.1. Environmental impacts**

Landslides have significant impacts on the natural environment, including:

- Earth's topography: Landslides affect the shape and structure of the Earth's surface.
- Water systems: They influence rivers, streams, and groundwater flow, altering their character and quality.
- Forests: Landslides can have detrimental effects on the forests that cover a significant portion of the Earth's surface.
- Wildlife habitats: The habitats of diverse wildlife, including those found in rivers, lakes, and oceans, are affected by landslides.

The downslope movement of large landslide masses has a profound effect on mountain and valley systems on both land and beneath oceans. Some landslides can extensively alter the terrain, affecting rivers, farmland, and forests. Forests, grasslands, and wildlife are often negatively impacted by landslides, with forest and fish habitats being particularly vulnerable to damage or temporary destruction.

Landslides, which are frequently triggered by seismic activity, floods, or volcanic eruptions, have the potential to initiate subsequent hazards. For instance, an earthquake-triggered landslide can result in a perilous tsunami if a substantial quantity of landslide material cascades into a body of water, causing a significant displacement of water volume. Similarly, a volcanic eruption or earthquake-induced landslide can obstruct the flow of a river, leading to the accumulation of water upstream. Should the dam formed by the landslide material fail, there would be a sudden release of impounded water downstream, potentially causing flooding. This flooding can have far-reaching consequences, including the erosion and destabilization of riverbanks and coastal regions, as the rapid saturation of slopes and the undercutting of cliffs and banks. Consequently, it is imperative to comprehensively examine all potential natural hazards when evaluating the vulnerability of an area to landslides. Regrettably, the current availability of maps depicting susceptibilities to multiple hazards remains limited. In most cases, if hazards are even mapped, only a solitary hazard is considered, failing to capture the full spectrum of risks present in an area.

Despite the negative consequences, landslides also play an ecological role that is often ignored. They contribute to both aquatic and terrestrial biodiversity. Debris flows and other forms of mass movement are vital in providing sediment and coarse woody debris, which maintain the habitat diversity of streams, including pool and riffle formations. Recent ecological studies indicate that under specific conditions, landslides can actually benefit fish and wildlife habitats by improving the habitat of organisms they rely on for food (Highland and Bobrowsky, 2008).

#### **1.2.2.2. Social impacts**

Landslides tend to disproportionately affect vulnerable populations, exacerbating existing social inequalities. Marginalized communities living in hazardous areas often lack the resources and means to respond effectively to landslides. Limited access to early warning systems, evacuation shelters, and financial assistance amplifies their vulnerability. Thus, landslides perpetuate social disparities and highlight the need for equitable disaster preparedness and response strategies.

The emotional and psychological toll of landslides should not be overlooked. Survivors may experience trauma, grief, and anxiety, leading to long-lasting mental health issues. The collective trauma experienced by communities can strain social bonds and disrupt social cohesion. Support systems, including counselling and community outreach programs, are crucial in addressing the psychological aftermath of landslides.

Landslides have profound social consequences that extend beyond the physical damage. Recognizing and understanding the social impact of landslides is essential for fostering resilience and mitigating future risks. Building awareness, implementing effective early warning systems, improving land-use planning, and promoting community engagement are key steps in reducing the social vulnerabilities associated with landslides. By prioritizing these measures, societies can work towards creating safer, more resilient communities that are better equipped to cope with the social impacts of landslides and other natural hazards.

#### **1.2.2.3. Economic impacts**

Residential areas constructed on unstable slopes can suffer varying degrees of damage, ranging from partial to complete destruction. Landslides can destabilize or destroy foundations, walls, surrounding property, as well as both above-ground and underground

utilities. The effects of landslides on residential areas can occur on a large scale, affecting numerous dwellings, or on an individual basis, where only a single structure or part of a structure is affected. Additionally, when a landslide damages the essential infrastructure of one property, such as trunk sewer, water, or electrical lines, and common-use roads, it can disrupt the lifelines and access routes of other nearby properties. Commercial structures are also susceptible to the impacts of landslides, experiencing similar consequences to residential structures. This is particularly significant for common-use structures as their operations may be interrupted due to landslide damage to the structure itself and/or damage to access roadways.

Fast-moving landslides, like debris flows, pose the greatest threat to structures due to their destructive nature, high velocity and powerful force. These landslides often occur suddenly and without warning, making it difficult to implement mitigation measures. Steep areas are particularly susceptible to rapid destruction caused by debris avalanches and lahars, which can severely damage cities, towns, and neighborhoods (Coe et al., 2014). It is challenging to rebuild in affected areas due to the continuous movement of landslides, which may persist for days, weeks, or months. Rebuilding efforts are not always successful in ensuring stability. The transportation industry is significantly impacted by landslides, affecting a large number of people globally. Failures along roads and railways, including cut and fill failures, as well as collapses due to weak and slide-prone soils, are common problems. Rockfalls can cause harm to individuals and infrastructure. All types of landslides can result in temporary or long-term closures of vital routes used for commerce, tourism, and emergency activities, as they become blocked by dirt, debris, or rocks. Even slow creep can disrupt linear infrastructure and create maintenance issues. Landslides frequently block major highways worldwide, necessitating bulldozing or excavation to clear the roads. With increasing global population, the vulnerability to landslide hazards grows. People are often compelled to settle in previously considered hazardous areas due to limited available land. Inadequate land-use policies allow construction on land that would be better suited for agriculture, open-space parks, or other purposes instead of dwellings and structures. Communities often lack the necessary preparedness to regulate unsafe building practices, either due to political limitations or a lack of expertise (Highland and Bobrowsky, 2008).

Table 1.6 displays some examples of catastrophic landslide disasters that have had severe impacts on communities worldwide. It is important to note that landslides can occur in various regions and are influenced by factors such as geology, climate, and human activities. Building

resilience, implementing early warning systems, and adopting appropriate land-use planning measures are crucial in mitigating the risks associated with landslides.

Table 1.6. The catastrophic historical landslide disasters.

Name and date	Reason and Location	Consequences
Vaiont Dam Disaster 09.10.1963	The failure of a mountainside led to a massive landslide, which generated a mega tsunami that overtopped the Vaiont Dam.	2,000 people died
Aberfan Disaster 21.10.1966	Longarone, Italy A large coal waste tip collapsed, triggering a landslide that engulfed a primary school and nearby houses.	144 people died, most of whom were children.
Armero Tragedy 13.11.1985	Wales The eruption of the Nevado del Ruiz volcano triggered a catastrophic mudflow known as a lahar, which buried the town of Armero.	25,000 people died.
Chittagong Hill Tracts Landslides 11.06.2007	Colombia Intense monsoon rains caused widespread landslides in the hilly region of Chittagong.	Resulted in over 130 fatalities and displaced thousands of people.
Zhouqu Landslide	Bangladesh Heavy rainfall triggered a massive landslide in Zhouqu County.	1,400 people died and caused extensive damage to infrastructure and property.
Sierra Leone Landslide 14.08.2017	Gansu Province, China Heavy rainfall caused a large landslide in the Regent area of Freetown.	Resulted in over 1,000 fatalities and widespread destruction of homes and infrastructure.
Mocoa Landslide 01.04.2017	Sierra Leone Torrential rains triggered a landslide that struck the city of Mocoa. Colombia	The event caused the deaths of more than 300 people and led to significant damage to residential areas.

### 1.3. Occurrence and Impact of Fire

#### 1.3.1. Occurrence of Fire

Fires can have catastrophic consequences, resulting in substantial damage to both the property and human life. Tragically, fires exhibit an indiscriminate nature and are capable of transpiring without regard to location or temporal constraints. Consequently, acquiring knowledge regarding primary catalysts is of utmost significance for proactively mitigating their likelihood.

## **Classification of Fires**

### ***Based on the nature of the burning material:***

The rapid spread of fire once ignited can pose challenges in effectively addressing its growth. The approach to combating a fire is not always straightforward, as fires can vary significantly in their characteristics. Different fires present distinct hazards and risks, making it crucial to consider appropriate measures. Incorrect utilization of fire extinguishers can exacerbate the situation rather than resolving it. There exist 6 distinct classifications of fires based on the nature of the burning material (<https://www.haspod.com/blog/fire/classes-of-fire>):

- Class A (Involving solids)
- Class B (Involving liquids)
- Class C (Involving gases)
- Class D (Involving metals)
- Electrical fires
- Class F (Involving cooking fats and oils)

Each fire type necessitates specific techniques for extinguishment, contingent upon the associated hazards.

**Class A fires** involve solid fuels, which can include materials such as paper, cardboard, furniture, fixtures, fittings, and even the building structure itself. These fires are considered "normal" fires that typically involve solid combustible materials. Class A fires are among the most prevalent types of fires since solid fuels are widespread and challenging to eliminate entirely. Implementing proper housekeeping practices, such as reducing the accumulation of materials like packaging and waste, can help minimize the associated risks. Water and foam extinguishers are considered the most effective options for combating Class A fires. Water, in particular, is widely utilized due to its ability to tackle most fires involving solid fuels. However, it is crucial to note that water is a conductor of electricity and should never be

employed in the vicinity of electrical equipment to avoid the risk of electrical shock or further damage.

**Class B fires**, which involve flammable liquids, are more frequently encountered in industrial settings where substantial quantities of various fluids, liquids, and chemicals are employed. Examples of such substances include cleaning fluids, solvents, fuels, inks, adhesives, and paints. Although Class B fires are relatively uncommon, they pose a greater level of danger compared to other fire types. Therefore, it becomes imperative to prioritize personal protection by implementing appropriate measures. In order to ensure personal safety, it is essential to familiarize oneself with the specific flammable liquids used in the workplace and conduct a Control of Substances Hazardous to Health (COSHH) assessment. Adhering to legal requirements, COSHH assessments are mandatory for any hazardous substances. During the assessment, due consideration should be given to the safe storage and proper utilization of these substances. It is crucial to store them in clearly labelled containers and keep them away from potential ignition sources. Foam and powder extinguishers are the most effective types for tackling Class B fires. CO<sub>2</sub> extinguishers can also be used but have limited effectiveness.

**Class C fires** refer to fires that involve gases, which can include natural gas, LPG (liquefied petroleum gas), or other types of gases capable of forming a flammable or explosive atmosphere. Working with gases entails inherent dangers and increases the risk of fires. It is crucial to store gases in sealed containers within designated safe storage areas, and it is imperative that gas-related tasks are performed exclusively by competent individuals. The safest approach to extinguishing this type of fire is by promptly shutting off the gas supply. Once the gas supply has been cut off, the most effective type of extinguisher to combat the fire is a dry powder extinguisher.

**Class D fires** involve certain types of metals that can be combustible, such as sodium, despite metals not commonly being perceived as flammable materials. Additionally, metals have excellent conductivity, facilitating the spread of fires. Elevated temperatures can cause all metals to soften and melt, leading to potential structural collapse when metal joists and columns are present in a fire. It is crucial to note that water extinguishers should not be used on Class D fires since water can actually act as an accelerant on metal fires, exacerbating the situation. There are dry powder extinguishers specifically developed to combat metal fires. The composition of the powder inside the extinguisher may vary depending on the specific

type of metal risk it is designed to address. In some cases, small metal fires can be smothered using dry earth or sand as an alternative approach.

**Electrical fires**, while not classified separately as Class E fires, present distinct hazards. The ignition source in these fires is electricity itself rather than a fuel, but fires in live electrical equipment introduce additional risks. They are not assigned their own dedicated class designation since they can fall into any existing fire classifications. This is because it is not the electricity that burns but rather the surrounding material ignited by the electric current. To mitigate the risks associated with electrical fires, it is vital to ensure the correct installation, inspection, and maintenance of electrical equipment and installations. Using water or any other conductive substance to extinguish an electrical fire can be fatal due to the risk of electric shock. The most suitable type of fire extinguisher for electrical fires is a CO<sub>2</sub> extinguisher. Additionally, certain dry powder extinguishers are appropriate for low-voltage situations. Whenever feasible, it is recommended to shut off the power supply to the affected area in order to minimize the intensity and spread of the fire.

**Class F fires**, also known as cooking oil or fat fires, often arise from deep fat frying and spillages of flammable oils near heat sources in kitchens. While commonly found in commercial kitchens with deep-fat fryers, such fires can also occur in residential settings. It is crucial never to leave food or frying equipment unattended while in use to minimize the risk of these fires. Extinguishing Class F fires can be challenging due to the intense heat generated by the burning oil. It is important to note that using the wrong type of extinguisher can exacerbate the situation by spreading the fire through the burning oils and fats. The only approved fire extinguisher for effectively combating cooking oil and fat fires is the wet chemical extinguisher. Additionally, for small Class F fires, a fire blanket can also be employed as a suitable alternative.

The characteristics of each fire and their extinguisher methods are summarized in Table 1.7.

Table 1.7. The characteristics of each fire and extinguishing methods.

Class of Fire	Type of fuel	Methods of Fire Suppression and extinguisher type
Class A	Solid	Smothering, water
Class B	Liquid	Smothering, foam and powder extinguishers
Class C	Gas	Smothering, dry powder
Class D	Metal	Dry powder agent
Electrical fire	Electricity	Non-conductive chemicals
Class F	Cooking oil or fat	Smothering, wet chemical and wet blanket

***Based on the location of fire:***

#### **House fires:**

The house fire refers to the inherent risk posed by both unintentional and deliberate fires, which have the potential to endanger lives as well as compromise the structural integrity and safety of the property itself. Between the years 1993 and 2015, a cumulative sum of 86.4 million fire incidents has resulted in over one million fatalities caused by fires (Brushlinsky et al., 2017). Furthermore, the collective yearly economic losses incurred worldwide due to the hazards posed by fires account for approximately 1% of the global Gross Domestic Product (GDP) (Bulletin, 2014).

Frequent causes of house fires include:

- Cooking Equipment
- Smoking
- Candles
- Faulty wiring
- Barbeques
- Children playing with fire
- Lightning equipment

- Heating equipment

House fires can mainly be attributed to overheating of cooking equipment. It was reported that cooking is the leading cause of fire in both residential and non-residential buildings (USFA, 2016). Within seconds, flames can intensify, engulfing the kitchen in a devastating fire due to several factors including the presence of a significant quantity of flammable household materials and the improper storage of tools, waste, equipment, and volatile substances such as liquid petroleum gas, paints, ammunition, and more (Kodur et al., 2020). Consequently, it is imperative to be constantly alert and avoid leaving the kitchen unattended, particularly during cooking activities. Neglecting this precaution not only risks burning kitchen products, but also endangers property by inviting potential fire hazards. It is recommended that paper towels, oven mitts, and dish towels be kept away from the stove or other heat sources to avoid a household fire hazard.

Smoking can pose many threats that not only endanger personal health but also act as a primary catalyst for potentially deadly fire events. Statistics show that more than 1,000 fires in residential buildings are responsible for smoking in a single year. A lit cigarette, even if it comes into contact with the fabric of a curtain or accidentally falls on a pile of clothing, can quickly turn into a fire, putting the entire house in danger. The most effective solution to reduce the occurrence of such common fire incidents is to strictly avoid smoking indoors, whether in residential or commercial buildings. The choice to smoke outside significantly reduces the risk of house fires. However, the ideal course of action would be to encourage smokers to abandon their bad habits completely, thereby providing an even higher level of safety and well-being (<https://www.firetechglobal.com/top-10-common-fire-incidents-and-how-to-prevent-it/>).

### **Industrial Fire:**

Common causes of industrial fires include:

- Faulty or malfunctioning equipment
- Flammable materials or substances
- Electrical faults or short circuits
- Welding or hot work operations
- Combustible dust explosions

- Human error or negligence in following safety protocols.

Equipment that is faulty or malfunctions is a frequent cause of industrial fires. When machinery, tools, or systems do not function properly, it can lead to overheating, sparks, or electrical failures that can ignite flammable materials or substances present in the industrial setting. Regular inspection, maintenance, and prompt repair of equipment are essential to prevent such incidents. Additionally, proper training and adherence to safety protocols can help identify and address equipment issues before they escalate into fires.

The flammable materials or substances are significant causes of industrial fires. When highly flammable materials, such as fuels, solvents, gases, or combustible dusts, come into contact with an ignition source, they can rapidly catch fire and lead to significant fire incidents. Proper storage, handling, and segregation of flammable materials, along with effective fire prevention measures, such as eliminating potential ignition sources and implementing appropriate ventilation systems, are essential in reducing the risk of fires caused by the ignition of flammable substances in industrial settings. Chemical spills or leaks also cause ignition. When hazardous chemicals are mishandled, improperly stored, or accidentally released, they can come into contact with ignition sources, leading to fires or explosions. Strict adherence to proper handling, storage, and containment procedures for chemicals, along with comprehensive training for employees, can help prevent and mitigate the risks associated with chemical spills or leaks. Improper storage or handling of hazardous materials such as inadequate containment measures, improper labelling, incompatible storage of different hazardous substances, failure to segregate flammable materials from ignition sources, and insufficient ventilation in storage areas are also significant factors in the control of the industrial fires. Using appropriate containers, ensuring proper ventilation, implementing segregation measures, providing clear labelling, training employees on safe handling procedures, regular inspections and maintenance of storage areas are necessary to identify and address any potential hazards.

Electrical faults or short circuits are another prominent cause of industrial fires. Issues with electrical systems, such as faulty wiring, overloaded circuits, or equipment malfunctions, can generate heat, sparks, or electrical arcs that can ignite nearby flammable materials. Regular inspection and maintenance of electrical systems, proper installation and grounding, and adherence to electrical safety standards are crucial preventive measures. Promptly addressing any electrical issues and providing adequate training on electrical safety for employees can

help mitigate the risks associated with electrical faults or short circuits. Inadequate fire safety measures and precautions significantly contribute to industrial fires. When appropriate fire prevention and protection measures are lacking or insufficient, the risk of fires increases. Inadequate fire detection systems, lack of proper fire extinguishing equipment, insufficient employee training on fire safety protocols, poor maintenance of fire safety equipment, and failure to implement effective evacuation plans and emergency procedures are common deficiencies. To mitigate this risk, prioritizing robust fire safety measures is essential. This includes regular inspections, installation of adequate fire detection and suppression systems, comprehensive employee training programs, and consistent adherence to fire safety regulations and guidelines.

Welding or hot work operations pose a significant risk of industrial fires. The intense heat generated during welding, cutting, soldering, or other hot work activities can easily ignite nearby flammable materials or substances. Sparks, molten metal, or hot slag can act as ignition sources, leading to fire incidents. To prevent fires during welding or hot work operations, it is crucial to implement proper fire prevention measures. This includes ensuring a clear and safe work area, removing flammable materials or protecting them with appropriate fire-resistant barriers, having fire extinguishing equipment readily available, and implementing hot work permits and safety protocols. Adequate training and supervision of personnel involved in welding or hot work activities are also essential to maintain a safe working environment and prevent fire incidents.

Combustible dust explosions are a significant cause of industrial fires. When fine particles of combustible materials, such as dust or powders, become suspended in the air and encounter an ignition source, it can result in a rapid and violent explosion. Industries such as manufacturing, woodworking, chemical processing, and food processing are particularly susceptible to combustible dust explosions. Preventing such incidents requires thorough housekeeping practices to control dust accumulation, proper ventilation systems to minimize dust suspension, regular equipment maintenance to prevent malfunctions that could generate sparks, and implementing explosion protection measures such as explosion venting or suppression systems. Comprehensive training for employees regarding the risks associated with combustible dust and proper handling and clean-up procedures is vital to reduce the potential for combustible dust explosions and subsequent fires (<https://csafire.com/industrial-fire-protection-and-workplace-safety/>).

## **Wildfire:**

A wildfire is an uncontrolled fire that happens spontaneously in a natural area like a forest, grassland, or prairie. It can start because of human activities or natural events like lightning, and it can occur at any time and anywhere. The origins of approximately half of documented wildfires remain uncertain or unknown. The risk of wildfires goes up when conditions are very dry, like during a drought, and when strong winds are present. Wildfires can cause major disruptions to transportation, communication, power and gas services, and the water supply. They also harm the air quality, and result in the loss of homes, crops, natural resources, animals, and even people's lives.

It was reported that anthropogenic climate change generates warmer and drier conditions, thus increasing the risk of wildfire. Human activities have the potential to directly influence the wildfires by igniting and suppressing fires, and indirectly by modifying the vegetation structure and composition, and by fragmenting the landscape (Jones et al., 2020).

### **1.3.2. Impact of Fire**

#### **1.3.2.1. Environmental impacts**

- ✓ **Air pollution:** Wildfires are known to emit smoke, various gases, and soot, contributing to air pollution. Remarkably, during the 2017 North American fire, smoke was propelled into the stratosphere, encircling the globe in just under two weeks—a phenomenon more commonly associated with volcanic eruptions rather than wildfires. The smoke and soot particles released during wildfires augment the concentration of fine particulates (diameter  $< 2.5 \mu\text{m}$ ) in the atmosphere. These particulates pose significant health risks. Moreover, the wind can carry these particles over long distances, leading to instances where particulates from fires in Mexico and Central America have reached as far as Texas and Southern America. In addition to particulates, wildfires can produce smog by releasing substantial amounts of carbon monoxide, nitrogen oxides, and volatile organic compounds (VOCs). When exposed to sunlight, these gases can trigger the formation of ground-level ozone, a pollutant known to cause health issues such as coughing and throat irritation. The combination of these emissions from wildfires underscores their substantial impact on air quality and public health (Keller et al., 2015).

- ✓ **Erosion:** Wildfires have significant implications for erosion on the soil. The intense heat from the fires causes burnt materials to seep into the soil, creating a waxy layer on soil particles. This layer hinders water infiltration during rainfall. Additionally, the destruction of plant roots due to the fire weakens their ability to hold the soil in place, leading to increased erosion. Steep slopes are particularly vulnerable to erosion, and areas that already experience frequent erosion will be further exacerbated by the loss of vegetation cover caused by the wildfires (Zavala et al., 2014).
- ✓ **Secondary hazards like flood and landslide:** Moreover, erosion resulting from wildfires can give rise to secondary hazards such as flooding and landslides in the immediate aftermath of the fire event. Subsequent heavy rainfall following a wildfire can substantially elevate the likelihood of landslides. Typically, debris flows can persist for 2 to 3 years after wildfires, after which they are no longer triggered by regular rain events. For instance, in 2017, an intense and brief rainfall caused debris flow along the Montagna Del Morrone following a wildfire event.
- ✓ **Reducing vegetation:** Wildfires have a significant detrimental effect on vegetation cover, as they often lead to the substantial burning of plant life, whether it be in a forest or a savannah environment. In regions where wildfires are frequent occurrences, many plant species have evolved adaptations to withstand the fires, such as developing thick barks. However, certain plant species, like mesquite and juniper, which are more susceptible to fire, cannot survive and ultimately die as a result of these intense events. Trees and plants play a crucial role in the natural process of absorbing carbon dioxide and releasing oxygen. When we experience a loss of trees, the carbon dioxide remains in the atmosphere, exacerbating the problem of global warming.
- ✓ **Loss of habitat:** Typically, the majority of animals have the ability to escape from wildfires. However, exceptionally large and intense fires can pose a lethal threat even to the fastest creatures (Nappi et al., 2004). Astonishingly, the 2019/20 Australian bushfire resulted in the loss or displacement of approximately 3 billion animals. Furthermore, species that reside in trees and depend on plants for shelter also suffer the consequences of habitat destruction. For instance, wildfires in the Pacific Northwest of the United States are now posing an increasing threat to the endangered Northern Spotted Owl, which relies on the forest for its habitat.

### 1.3.2.2. Social impacts

- ✓ **Injuries and fatalities:** Workplace fires can lead to injuries and fatalities, with profoundly distressing outcomes. Among the most prevalent causes of injuries in such fires are burns and smoke inhalation. Depending on the extent of the burns, victims may necessitate comprehensive medical care, which could involve surgery, skin grafts, and extensive rehabilitation. Smoke inhalation can also result in severe respiratory issues, such as asthma or lung damage, imposing long-term health implications on the affected individuals.
- ✓ **Emotional trauma:** Observing a fire incident or enduring the loss of a coworker in a fire can have profound emotional repercussions, potentially resulting in anxiety, depression, and post-traumatic stress disorder (PTSD). Employees who go through a workplace fire may feel deeply disturbed and vulnerable, finding it challenging to cope with the aftermath of the event. Even if they are not physically injured, the emotional distress they experience can significantly impact their capacity to work and carry out their daily responsibilities.
- ✓ **Occupational health and safety issues:** Workplace fires can give rise to potential occupational health and safety concerns. The fires can release hazardous materials, including smoke, chemicals, and toxic substances, posing a significant risk to the well-being of employees, especially those in close proximity to the fire or involved in the cleanup process. Furthermore, firefighters and other first responders who attend to the fire may also face the risk of exposure to these hazardous materials. Ensuring the safety of all personnel involved becomes crucial in such situations to prevent any potential health hazards.

### 1.3.2.3. Economic impacts

- ✓ **Property damage:** Fires can result in substantial property damage, encompassing buildings, vehicles, and personal possessions. The impact can be particularly severe in workplace settings due to the presence of valuable equipment, inventory, and critical documents. For example, a fire occurring in a manufacturing facility has the potential to devastate expensive machinery, raw materials, and finished products.

- ✓ **Business interruption:** Business interruption represents a noteworthy outcome of fires.

Even if the fire itself does not cause any direct property damage, the workplace often requires closure for a period to undergo cleaning and repairs. This can lead to revenue loss and the potential alienation of customers. Moreover, the downtime can prevent employees from working, resulting in decreased productivity and income for both the workforce and the business as a whole.

- ✓ **Litigation:** Workplace fires can lead to potential litigation as an outcome. In the event of injuries or fatalities resulting from a fire at the workplace, the employer may be held accountable and subject to legal proceedings. Such litigation can prove to be expensive and time-consuming, tarnishing the employer's reputation. The costs of legal fees, settlements, and other related expenses can accumulate rapidly, exerting a substantial impact on the financial stability of the business.

- ✓ **Increased insurance premiums:** Workplace fires can lead to the potential consequence of increased insurance premiums. Following a fire incident, a business might experience a rise in its insurance premiums. Insurance companies perceive businesses that have encountered fires as being at higher risk and more prone to future claims. Consequently, insurers may adjust the premiums for the business's property and liability insurance policies accordingly. Such elevated premiums can have a significant impact on the business's financial performance.

- ✓ **Damage to brand reputation:** Another noteworthy outcome of workplace fires is the damage to brand reputation, especially when the incident garners media coverage. Fires at businesses can attract considerable media attention, which in turn negatively impacts the company's brand reputation. Customers may perceive the business as unsafe or unreliable, resulting in a loss of trust and reduced revenue. Moreover, negative publicity can spread rapidly through social media, exacerbating the harm to the business's reputation. This impact on brand reputation can be particularly devastating for small businesses, as they may have limited resources to recover from the damages caused by the fire.

- ✓ **Financial losses:** Workplace fires can result in substantial financial losses. The costs associated with repairing or replacing damaged equipment, materials and property can accumulate rapidly and have a significant impact on a business's finances. Additionally,

the interruption of normal operations or temporary closures can lead to a loss of revenue. For small businesses with limited financial resources, these challenges can be particularly daunting. In some cases, the financial burden may be so severe that the business cannot recover, potentially leading to permanent closure.

- ✓ **Regulatory fines and penalties:** Workplace fires may result in potential regulatory fines and penalties, particularly if the fire occurred due to safety regulation violations. Regulatory bodies like OSHA (Occupational Safety and Health Administration) may conduct investigations to ascertain if any safety regulations were breached during the incident. In case violations are discovered, the agency can impose substantial fines and penalties on the business. These financial repercussions add to the overall losses caused by the fire, further amplifying the impact on the business's financial standing.

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