ENVIRONMENTAL GEOSCIENCES

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Lecture-16

Geological Hazards - Floods

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are now continuing with module three. In lecture one, we have already covered dip and strike, folds and faults, and their environmental interpretation. In lecture two, we completed the topic of geological hazards, specifically earthquakes. Then, in lecture three, we covered the geological hazards related to volcanoes.

Today, we will discuss the geological hazards related to floods. In this lecture, important concepts will be covered, such as geological hazards like floods, an introduction to floods, types of floods, physical characteristics, causes of floods, effects of floods, and strategies for reducing flood hazards. Now, we will understand this subject. A geological hazard is a phenomenon associated with geological processes that can produce a disaster when a critical threshold is exceeded and can result in significant loss of life or property. Floods are a significant geological hazard because they profoundly impact the Earth's surface processes, ecosystems, and human settlements. These hazards result from a complex interplay of natural geological and hydrogeological processes, often exacerbated by human activities.

Floods are the most ubiquitous of the geological hazards and affect more people than all other hazards combined. One positive aspect of most floods is that their forecasting and warning can be more predictable than other geological hazards like earthquakes and landslides. Now, what is a flood? Floods are an excessive overflow of water that submerges land which is usually dry. They are caused by the volume of water within a body of water, such as a river or lake, exceeding its capacity and overflowing its banks due to factors like heavy rainfall, rapid snowmelt, or obstruction of the water flow.

Some floods are the result of unusual events such as the collapse of a dam, but the vast majority are perfectly normal and to some extent a predictable part of the natural

functioning of streams. In simple terms, a flood is any overflow of water onto land that normally remains dry. Now, the types of floods. In geology, floods are characterized as flash floods, river floods, coastal floods, pluvial floods, groundwater flooding, glacial lake outburst floods, dam break and reservoir floods, urban floods, and ice jams. They are categorized on the basis of causes, magnitude, frequency, and impact.

Now, one by one, we will understand the different types of floods. First is the flash floods. Floods occurring within six hours, mainly due to heavy rainfall associated with towering cumulus clouds, thunderstorms, tropical cyclones, or during the passage of cold weather fronts, or by dam failure or other river obstructions. This type of flood requires a rapid localized warning system. Flash floods occur due to a high rate of water flow as well as due to poor permeability of the soil.

Second is the fluvial floods, that is, river floods. Floods caused by precipitation over a large catchment area, melting of snow, or both. It builds up slowly or on a regular basis, and these floods may continue for days or weeks. The major factors of these floods are moisture, vegetation cover, depth of snow, size of the catchment basin, etc. Coastal floods are associated with cyclonic activities like hurricanes and tropical cyclones, etc., generating catastrophic floods from rainwater which often aggravate wind-induced storm surges along the coast. Pluvial floods occur when heavy rainfall creates a flood independent of an overflowing water body. They are very common in flat areas where water collects and does not drain quickly.

Groundwater flooding is the next type of flood. It occurs when the water table rises to a point where water emerges on the ground surface, saturating the soil and flooding the area. This type of flooding is typically not directly linked to heavy rainfall or overflow from rivers. Instead, it can occur due to a gradual buildup of water underground, which slowly seeps to the surface or near the surface. Glacial lake outburst flood.

Many of the big glaciers that have melted rapidly have given birth to a large number of glacial lakes. Due to the faster rate of ice and snow melting, possibly caused by global warming, the accumulation of water in these lakes has been increasing rapidly, resulting in the sudden discharge of large volumes of water and debris, causing flooding downstream. In the figure, you can see the GLOF is shown, which remains downstream. Dam break and reservoir floods are the next type. Due to the sudden failure of a dam or reservoir, releasing large amounts of stored water, it can occur in valleys or low-lying regions downstream of the dams. Next is the urban flood.

As land is converted from agricultural fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Urbanization decreases the ability to absorb water two to six times over what would occur on natural terrain. So during periods of urban flooding, streets can become swift-moving rivers, while basements can become death traps as they fill with water. A picture is shown with the sudden failure of a dam. The next type of flood is the ice jam.

An ice jam is a phenomenon that occurs in rivers in cold climates. Chunks of ice accumulate at a particular point and obstruct the flow of water. You can see this in the diagram given below. This blockage can lead to sudden and severe flooding upstream as the river's natural course is impeded. Meanwhile, downstream areas may experience reduced water flow until the jam breaks.

You can see in the figure the flow in the river and the deposition of the ice jam. Because of this, the downstream area has reduced water flow until the jam breaks. So this is about the different type of flood, which is the ice jam. Now, the physical characteristics of floods. The physical characteristics of floods are closely tied to the natural features and processes of floodplains, floodwaters, flood stages, floodways, and flood fringes. Here is an overview of these terms and their relationship to floods. The first one is the floodplain.

It is the relatively flat area adjacent to a river or stream that is periodically submerged during high water events. It is formed by sediment deposition from repeated flooding over time. The figure is an example showing the floodplain. Second is the floodway. These are channels designated as areas designed to carry floodwaters safely through or around a community.

It is often naturally formed by rivers or artificially designated by engineers. Third is the flood fringe. The portion of the floodplain outside the floodway that is still subject to flooding but experiences less velocity and depth of water is called the flood fringe. This area is commonly used for agriculture, parks, or low-risk developments, with flood mitigation measures. The next characteristic is the floodwater.

The water that overflows riverbanks or coastal areas during a flood event. It can be fresh or saline, depending on the source. It is capable of reshaping landscapes through erosion and deposition. The next characteristic is the flood stage. The level of water in a river or stream at which it overflows its banks and begins to submerge adjacent areas.

It can be measured in terms of height above a standard reference point, typically mean sea level. It is divided into stages like minor flooding, moderate flooding, and major flooding, reflecting increasing levels of impact. So this is all about the flood stage. Now, causes of floods. So we have learned what a flood is, then types of floods, then the physical characteristics of floods.

Now, causes of floods. Although the majority of flooding is caused by heavy rainfall, there is a wide variety of both geological processes and processes induced by human intervention that produce flood conditions. The first cause is geological causes. Here you can see. Within the geological causes, the first is excess precipitation. This is the principal cause of floods, as stream channels are typically designed to handle runoff from rainfall events that occur every two years. The occurrence of intense storms can exceed channel capacity, leading to flooding of adjacent areas like flood plains.

The second cause is snowmelt. Accelerated snowmelt due to abnormal weather combined with saturated or frozen ground significantly increases the risk of stream floods, as seen in regions like the Red River of North Dakota. Additionally, ice dams in northern climates block river flow, creating temporary lakes that can cause severe flooding when the ice barrier is breached. Next is ice dams. Flooding is a common occurrence in northern climates where river ice builds up and prevents normal river flow. The backup of such water forms a temporary lake condition that then reaches a critical threshold of impoundment, breaches the ice barrier, and results in downstream floods.

Next is glaciers. The most spectacular flooding on Earth was associated with what were originally termed the Spokane floods. The flooding was produced by the spillage of glacial Lake Missoula through a glacial ice barrier. Now, the second is human activity causes. The first point within it is urbanization.

By encroaching onto the floodplain and making the ground impervious to percolation, we have caused more and more floods in the region. Deforestation and poor cropping practices, stripping vegetation from previously forested slopes, and agricultural and grazing abuses of soil increase the size and frequency of floods. The third point is channelization. Confinement of a river by engineering works may aid the immediate area but can produce higher flood peaks in downstream reaches. Next is the issue of dams.

Faulty construction, poor geologic foundations, and induced environmental changes have caused many dam failures and tragedies. Now, the effects of floods. Each year, floods produce staggering losses throughout the world, killing thousands of people and countless

animals and costing billions of dollars in property destruction and commercial dislocations. Although major floods can now be predicted, they still cause ruinous societal damages. Primary effects are loss of life and injuries.

People and animals may be killed or severely injured by floodwaters, debris, and landslides. Structural damage: buildings, roads, bridges, and railroads are damaged by the strength of flood currents and erosion. The third one is utility damage: power lines, gas mains, sanitary lines, water lines, and telephone lines may get damaged or destroyed. Interruption of transportation and communication: destruction of transportation systems like roads and railways and communication systems delays recovery efforts. Erosion and undermining: highway and railroad beds are vulnerable to erosion, often leading to collapse or structural weakening.

Bridge failures are the next point. Bridge abutments can wash out, causing collapses and further disrupting transportation. Debris accumulation. Roads and airport runways can be blocked by debris, hindering the restoration of services. Destruction of industrial and business resources.

Industrial and business inventories are lost, leading to economic losses for enterprises. Agricultural losses. Crops and trees are destroyed. Farms lose grain, feed, equipment, and buildings. Farmlands may experience deep erosion, topsoil loss, or waterlogging, making them unsuitable for planting. Next is the economic impact on farmers.

Farmers incur significant financial losses due to the damage of crops, equipment, and long-term impacts on soil quality. Now, secondary effects, service disruptions, is the first point. Malfunctions in power and gas lines can lead to widespread disruptions in adjacent areas. Electrical fires from short circuits and explosions from damaged gas lines may occur. The second effect is chemical pollution. Floodwaters may carry hazardous chemicals if storage areas or containers are dislodged, contaminating land and water.

The third one is the chain reaction effects. Primary and secondary effects can cascade, increasing costs and disruptions significantly. Hunger and disease, disruptions in goods, services, and supplies can result in hunger, disease outbreaks, and human suffering. Contamination of water and sanitary systems poses ongoing health risks. Displacement and homelessness, families may be separated, individuals rendered homeless, and economic productivity lost.

Wildlife displacement. Animals, snakes, and rats driven from their habitats may infest human communities, introducing additional health hazards. Economic losses in education and commerce. Schools and businesses may close, leading to losses in education, employment, and commerce. Trade disruption.

Industrial goods may be delayed or lost, disrupting trade with other communities. Agricultural productivity loss. Fields and pastures may lose productivity due to erosion of topsoil or saturation with debris. Geographical changes. New river channels may form, affecting property lines and navigation.

Wildlife and ecosystem damage. Large floods can destroy food sources and breeding grounds, threatening wildlife populations. Seasonal impact: flood damage depends on the time of year, with summer floods being more damaging due to unfrozen soil and the presence of crops. Watershed conditions: the size and impact of floods depend on water set conditions, including vegetation, soil saturation, and terrain. Strategies for reducing flood hazards: floodproofing involves modifying structures to withstand flooding.

Examples include elevating buildings above the predicted flood level, as seen in the figure, using waterproof materials for construction in flood-prone areas, and installing barriers or flood walls around critical structures. The second strategy for reducing flood hazards is restrictive zoning. It designates flood-prone areas for uses less vulnerable to flooding, such as parks, agriculture, or conservation areas. It prevents high-density development in floodplains, minimizing potential damage. Next is retention ponds.

Artificial ponds are designed to capture and temporarily store excess stormwater runoff during heavy rainfall. They can reduce peak discharge into rivers, lowering flood risk downstream. Diversion channels: man-made channels that divert floodwaters away from populated or vulnerable areas. They can reduce the flood volume in the main river channel. They can protect urban centers, farmlands, and critical infrastructure.

The figure is also here for the retention pond and diversion channels. Next is the channelization. It is a general term for various modifications of the stream channel itself, usually intended to increase the velocity of water flow, the volume of the channel, or both. These modifications thus increase the discharge of the stream and, hence, the rate at which surplus water is carried away. The channel can be widened or deepened, especially where soil erosion and subsequent sediment deposition in the stream have partially filled in the channel.

So here, you can see the main channel and the flood level also. Next are the levees. They are raised embankments constructed along river banks to contain floodwaters. They prevent floodwaters from spilling into adjacent areas. But they can fail during stream floods or overtopping.

So artificial levees are designed to protect floodplain land from flooding by raising the height of the stream bank. Flood control dams and reservoirs. Yet another approach to moderating stream flow to prevent or minimize flooding is through the construction of flood control dams at one or more points along the stream. Excess water is held behind a dam in the reservoir formed upstream and may then be released at a controlled rate that does not overwhelm the capacity of the channel below it. Additional benefits of constructing flood control dams and their associated reservoirs may include the ability to use the water for irrigation, generate hydroelectric power at the dam sites, and develop recreational facilities for swimming, boating, and fishing at the reservoir.

So these are some of the effects of the dam. Just concluding the lecture, I have already discussed the introduction about floods. These are short-duration geological hazards causing significant losses. They result from natural processes like heavy rainfall and human-induced activities. Physical characteristics and types of floods occur when rivers overflow into floodplains.

The different types of floods are flash floods, river floods, coastal floods, pluvial floods, groundwater flooding, glacial lake outburst floods, dam break floods, reservoir floods, etc. Primary impacts include loss of life and infrastructure damage, while secondary impacts disrupt utilities and contaminate water. Strategies for reducing flood hazards include measures such as restrictive zoning, retention ponds, channel modification, levees, and flood control dams to manage water flow and reduce the geologic hazards that are floods. Thank you very much to all.