# Management and Planning Without Overflowing from the Riverbed

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## Abstract

Precautions taken to reduce risks before floods occur play a critical role in minimizing loss of life and property. Throughout history, civilizations have emerged and developed on river banks. In the development of these civilizations, streams have played a role in meeting the needs of drinking and utility water for settlements, irrigation water for agricultural areas, and, in later years, energy and industry. In recent years, floods have begun to occur due to changes in precipitation due to global climate change. The first step in this process is to determine areas at risk of flooding using scientific methods. Preparation of risk maps, limiting construction in these areas, and making appropriate land use plans are basic approaches. For structural design, it is important to estimate the magnitude of floods and the effects and efficiency of these structures on flood waves. For this purpose, cooperation should be established between local governments, central authorities, and relevant institutions, flood early warning systems should be established, and the public should be informed about these systems. In addition, flood-resistant infrastructure projects (such as sewer systems, flood dams, and stream rehabilitation) should be planned and implemented in advance. The society should be prepared for floods through education and awareness activities, and organizational preparation should be increased through pre-disaster drills. This study focuses on the definition of flood, types of floods, classification of floods, flood diversion, and flood protection principles, and aims to create public awareness.

**Keywords:** *Flood, Flood Control, Flood Mitigation, Climate Change*

## 1. INTRODUCTION

One of the most common natural disasters experienced across many countries worldwide is flooding, which occurs when a body of water exceeds its usual volume and river levels rise above their annual average. Humanity has been implementing various measures for centuries to protect itself from this disaster. Nevertheless, each year, hundreds of thousands of people lose their lives, become homeless, and suffer severe economic losses. In recent years, increases in temperature and precipitation values have been observed due to global warming. Especially when precipitation exceeds normal levels, it often leads to sudden flash floods.

In our country, flooding ranks second only to earthquakes among natural disasters and is not a phenomenon that can be fully controlled. Therefore, the aim of the measures taken is not to prevent floods entirely but to minimize their adverse impacts. Since its establishment in 1953, the General Directorate of State Hydraulic Works (DSİ) has been developing and implementing various projects to protect the country's water resources. Numerous structures have been constructed to control and mitigate the effects of flooding. These include dams, flood detention basins, flood diversion channels, and streambed rehabilitation works. However, it is also essential that other institutions in the region show sensitivity and cooperate with these efforts.

What is a flood, and why does it occur? A flood is the overflowing of a river from its bed or the inundation of inhabited or uninhabited land due to rising water levels from various causes. Despite today's accumulated scientific knowledge, floods—whether caused by natural processes or human intervention—continue to pose serious threats in our country and many parts of the world. Fundamentally, floods are natural events. However, it is predominantly human interference that transforms this natural phenomenon into a disaster with potential for loss of life and property.

The causes of floods can be categorized into two main dimensions: Natural causes: In many regions of the world today, precipitation levels have significantly exceeded long-term averages. Anthropogenic causes: Any human activity that is incompatible with nature or obstructive to natural systems increases the potential damage caused by floods and thus turns flooding into a disaster [1-4].

## 2. CAUSES OF FLOODS AND FLOOD FORECASTING

In flood forecasting, it is essential to process hydrometeorological data in accordance with hydrological principles and to consider qualitative information in the form of expert opinion. The underlying causes must be thoroughly examined, and preventive measures should be taken based on the specific conditions under which floods occur.

### 2.1. Unexpected conditions

**Natural Conditions:**
Since it is not possible to intervene in natural conditions, taking preventive measures in this regard is generally not feasible. Intense rainfall, sudden snowmelt, or ice jams that lead to the narrowing of flow cross-sections are typical examples of such conditions.

**Dam Failures:**
Dam failures may occur due to various factors such as insufficient spillway capacity, poor foundation conditions, or the failure to connect the impermeable core to a suitably impermeable foundation layer, which can result in seepage from underneath the structure.

**Tidal Events, Storms, and Earthquakes:**
Events such as oceanic tides, severe storms, and earthquakes are beyond human control. However, some precautionary measures may be taken in advance to mitigate their possible impacts.

**Geomorphological Conditions:**
These conditions are related to the natural characteristics of river basins, and as such, human intervention is not applicable.

**Human Interventions and Social Factors:**
Improper land use, deforestation, destruction of vegetation, unauthorized settlements within riverbeds, and erosion are primarily anthropogenic factors. These conditions can be managed, and the damage caused by floods can be minimized through appropriate mitigation measures. Additionally, heavy rainfall over a snow-covered river basin can result in rapid snowmelt, leading to severe flooding. Soil moisture levels during rainfall events also play a significant role in flood generation.

### 2.2. Meteorological Conditions

**a) Winter Precipitation-Induced Floods:**
Winter precipitation associated with well-developed westerly depressions and warm fronts is particularly influential in Central and Northern Europe. When the volume of precipitation is high, continuous, and prolonged, the soil becomes saturated, resulting in large volumes of surface runoff and subsequently, flooding.

**b) Summer Convective Storm-Based Floods:**
Convective storms triggered by significant temperature differences can produce extremely intense rainfall events, leading to severe and sudden flooding.

**c) Temperature Contrast (Convective) Storm-Driven Floods:**
Meteorological conditions frequently observed in Southeastern and Western Europe—including Turkey—often involve cold fronts interacting with convective systems.

These systems can move from the Mediterranean inland and result in extreme rainfall lasting more than 24 hours. This category includes snowmelt-induced floods, urban drainage overflows in densely populated areas, coastal storm surge and tidal floods, as well as floods caused by dam failures.

### 2.3. In Terms of Their Locations of Occurrence:

*River and stream floods
*Mountainous area floods
*Urban floods
*Coastal floods
*Fluvial (riverine) floods
*Storm surge inundation
*Seismic sea wave (tsunami) floods
*Flash floods
*Ice jam floods
*Debris or mudflows
*Groundwater-related flooding

## 3. DAMAGES OF FLOODS

**Direct Damages:**
These refer to visibly observable impacts such as structural collapse, mud deposition, scouring, and material displacement. Such damages are quantified based on the financial cost required for reconstruction or repair of affected areas.

**Indirect Damages:**
These include disruptions and losses in trade, economic activities, and public services due to flooding.

**Non-Monetary Damages:**
These are damages that cannot be expressed in monetary terms, such as loss of human life, health impacts, and threats to social and economic security. Efforts to study and mitigate flood damage began in the 20th century and have evolved through three successive phases:

**Hydraulic Structures Phase (1930–1960):**
In this period, infrastructure such as dams, retaining walls, levees, and diversion tunnels were constructed. Additionally, formulas and algorithms were developed to estimate flood peak discharges.

**Floodplain Management Phase (1960–1980):**
During this stage, measures such as early warning systems and land use planning were implemented to reduce flood risks.

**Monitoring and Control of Flood Structures Phase:**
This phase focuses on the operational management, inspection, and performance monitoring of existing flood protection structures to ensure their effectiveness and sustainability.

## 4. FLOOD MANAGEMENT

Flood management refers to the comprehensive set of planning, implementation, and response activities aimed at preventing flood risks, mitigating their impacts, and enhancing preparedness, particularly in areas surrounding rivers, streambeds, water resources, and coastal cities.

The primary objectives of flood management include preventing loss of life and property, reducing economic damages, minimizing environmental impacts, and ensuring sustainable water resource management.

### 4.1. Flood Management Process

**A. Flood Risk Assessment**
Collection of hydrological and meteorological data
Analysis of historical flood events
Mapping of high-risk areas (flood risk maps)

**B. Preventive Measures**
Stream rehabilitation and regulation of floodplains
Construction of dams, levees, and water storage structures
Integration of flood risk considerations into urban planning. Flood insurance schemes (e.g., TARSİM in Turkey)

**C. Early Warning and Evacuation Systems**
Meteorological alert systems
Emergency evacuation plans prepared by local authorities

**D. Emergency Response During the Disaster**
Search and rescue operations
Evacuation and first aid
Temporary shelter and food assistance

**E. Post-Disaster Recovery**
Damage assessment and compensation procedures
Infrastructure repair and restoration
Resettlement planning and post-disaster development strategies

### 4.2. Flood Management In Turkey

- The General Directorate of State Hydraulic Works (DSİ) is responsible for implementing flood protection projects.
- The Disaster and Emergency Management Authority (AFAD) includes flood hazards within its disaster management planning framework.
- Municipalities and Provincial Special Administrations are responsible for drainage and infrastructure planning at the local level.

The classification that should be taken into account in flood management, as proposed by Kenny (1990), is as follows.

**Flood Damage Zone I (Direct Flood Zone):**
Residential development should be prohibited in these areas. Only low-impact recreational uses, such as picnic areas, should be permitted.

**Flood Damage Zone II (Areas with alluvial fans and natural channels shallower than 1 meter):**
Very limited residential development may be allowed, and only in specific areas. Settlements should not be permitted within natural channels or valley floors.

**Flood Damage Zone III (Disconnected upper and lower basin areas, low-lying terrains, and erosion/transport zones with slopes generally less than 2%):**
Measures similar to those in Zone II should be implemented. Special attention should be paid to the design of culverts under roads.

**Flood Damage Zone IV (Areas with steep slopes, typically near mountainous regions in the upper parts of catchments, featuring valleys that are largely disconnected):**
Bridges, roads, and culverts should be designed to accommodate both floodwaters and boulders larger than 1 meter in diameter. Limited residential development may be permitted in flatter sections of these areas.

## 5. PRINCIPLES OF FLOOD PROTECTION

### 5.1. Planning Stage

In the planning phase, the design flood and the flood characteristics of the region are identified, along with the area to be protected. Applicable methods and protection measures are determined, and the cost and effectiveness of each measure in flood control are assessed. The optimal solution is selected based on achieving maximum benefit at minimum cost. An economic analysis is then conducted by comparing the costs and expected benefits of the proposed flood protection measures.

Flood calculations, particularly in the fields of hydraulics are significant subject in the field of engineering. These calculations are conducted to estimate the magnitude, frequency, and potential impacts of floods that may occur in a given region. Typically, they serve the following purposes:

- To assess flood risks
- To design structures such as dams, culverts, and bridges
- To plan residential and urban development areas
- To develop early warning systems

Key components include:
**a. Hydrological Analysis:**
Precipitation data: Maximum daily/hourly rainfall amounts.
Flood frequency analysis: Flood magnitudes and return periods are estimated using statistical distributions such as Gumbel and Log-Pearson Type III (e.g., 100-year flood).

**b. Hydraulic Modeling:**
Flow calculations: Discharge (Q) = Cross-sectional Area (A) × Flow Velocity (V). River channel capacity and flood extent: Water surface elevations and flood-prone areas are determined using software tools like HEC-RAS.

**c. Topography and Soil Data:**
Factors such as digital elevation models (DEM), soil permeability, and vegetation cover influence flood behavior.

**d. Flood Frequency and Return Period (T):**
For example, if a discharge of 550 $m^3/s$ is expected to occur once every 100 years in a specific region, the annual probability of such a flood is $P = 1/T = 1/100 = 0.01$, or 1%.
Alternatively, if the same discharge occurs every 50 years, the annual probability would be $P = 1/T = 1/50 = 0.02$, indicating a 2% chance of occurrence in any given year [5-9].

## 6. FLOOD CONTROL AND MITIGATION METHODS

For design flood assessments, the General Directorate of State Hydraulic Works (DSİ) uses recurrence intervals of 10, 50, and 100 years in small-scale flood hydrology projects such as detention basins, flood protection, and diversion channels. For larger structures, depending on the size of the facility and downstream conditions, design floods with return periods of 500 and 1000 years may also be considered.

In cases where the total storage volume is large, flood hydrographs are generated. For small-volume storage reservoirs ($\leq 10^6$ $m^3$), 100- or 500-year floods are used; for large-volume reservoirs ($>10^6$ $m^3$), if there is no or low risk to human life, 500- or 1000-year floods are considered; and in cases where there is a high risk to human life in large-volume reservoirs, risk analyses are carried out based on 10,000-year flood events.

The recurrence intervals for different types of structures are as follows: Earth-fill dams: 15,000 years; Rock-fill dams: 10,000 years; Concrete dams: 1,000 years; Levees near urban areas: 250 years; Levees in rural or remote areas: 100 years; Cofferdams: 25 years.

### 6.1. Flood Routing

Flood routing calculations offer numerous advantages in terms of flood control. When the magnitude of a flood is known at a specific location along a river, flood routing techniques can be used to estimate the flood magnitude at downstream locations many kilometers away several hours or even days in advance. Since flood routing enables the estimation of changes in discharge and water level along the river course, it provides a reliable basis for determining the dimensions of flood protection structures, such as levees. In the case of reservoirs, if the inflow flood hydrograph is known, flood routing allows the calculation of outflow discharges through spillways. This makes it possible to design the dimensions of spillways, determine cofferdam heights, estimate the maximum water level in the reservoir, and define both the height of the dam and the extent and duration of land submergence below the dam.In urban stormwater drainage systems, flood routing is used to model how a flood wave propagates through the network after intense rainfall. This helps identify which parts of the city are likely to be inundated.

By applying flood routing in reservoirs, the outflow discharges through spillways can be determined based on the inflow hydrograph. As a result, the appropriate dimensions of spillways, the required height of cofferdams, the peak reservoir water level, the height of the dam, and the extent and duration of submergence of land beneath the reservoir can all be accurately assessed. Similarly, in stormwater collection networks, flood routing enables the analysis of flood wave propagation through the system, which can be used to identify areas of potential urban flooding.

### 6.2. Non-structured Flood Control

For effective non-structural flood control, the following measures should be implemented:

- Developing a floodplain management plan and identifying flood risk levels,
- Establishing shelters or designated safe areas above projected flood levels for humans and animals,
- Installing flood forecasting and early warning systems,
- Planning rescue operations and ensuring effective flood response during events,
- Temporarily evacuating flood-prone areas when necessary,
- Prioritizing and completing critical activities in flood-prone areas before the flood season,
- Obtaining flood insurance coverage.

### 6.3. Structured Flood Control

For structural flood control, the following measures should be considered:

- Reducing flood runoff through soil conservation and watershed management practices,
- Regulating river channels by lowering the riverbed or increasing flow velocities within the cross-section to reduce floodwater levels,
- Diverting floodwaters using flood diversion channels or spillways,
- Attenuating peak flood discharges by temporarily storing part of the floodwater in detention basins, flood detention reservoirs, or dams,
- Containing flood flows within a designated floodway using levees, flood walls, or closed conduits [10-16].

## 7. FLOOD PROTECTION STRUCTURES

### 7.1. River Channel Regulation

By regulating the river channel, it is possible to reduce the harmful impacts of flooding by increasing the discharge capacity that the riverbed can convey above a certain water level. Widening or deepening the river channel is a feasible method, particularly for small rivers with channel widths up to 30–40 meters (Figure 1).

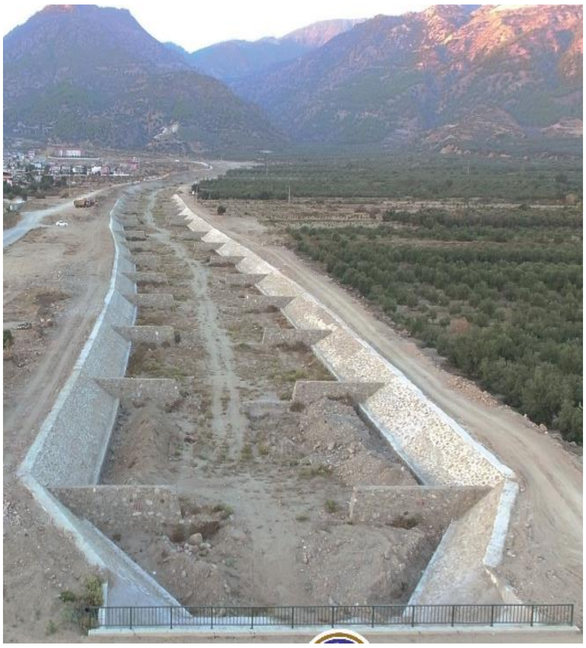


Figure 1. Rivel Channel Modification [17].

### 7.2. Flood Channel

In certain sections of a river where it is not feasible or advisable to modify the entire riverbed to convey all floodwaters, or where levee construction is impractical, a portion of the floodwater can be diverted into a flood diversion channel to reduce the flood load on the main river.

Where topographic conditions are favorable, the river may be transformed into a lake, or natural lakes can be modified to function as flood diversion channels (Figures 2 and 3).

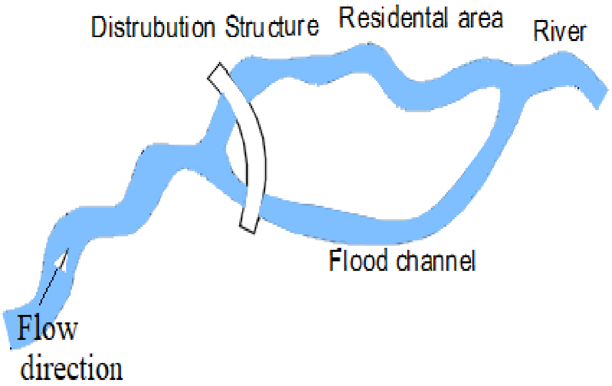



Figure 2. Flood Channel (A)

Flood detention basins are single-purpose flood control structures with non-regulated outlet systems, unlike dams and levees. These basins temporarily store floodwaters and release them back into the river channel in a delayed manner, at flow rates that do not pose a threat. In this way, the peak discharges of the flood hydrograph are reduced. Detention basins are typically located away from the main river channel and are characterized by large surface areas and shallow depths. Outside of the flood season, they can also be utilized as agricultural land. In terms of their impact on downstream flows:

Flood detention basins can be implemented in various configurations, such as:

- Basins designed without any river regulation,
- Basins planned in combination with partial river regulation measures,
- Basins constructed specifically to retain only extreme (maximum) flood events.

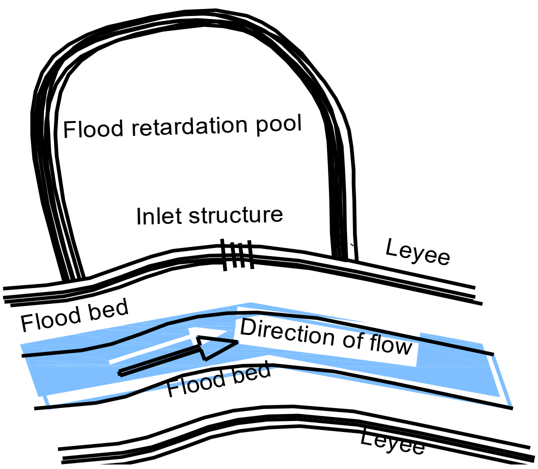
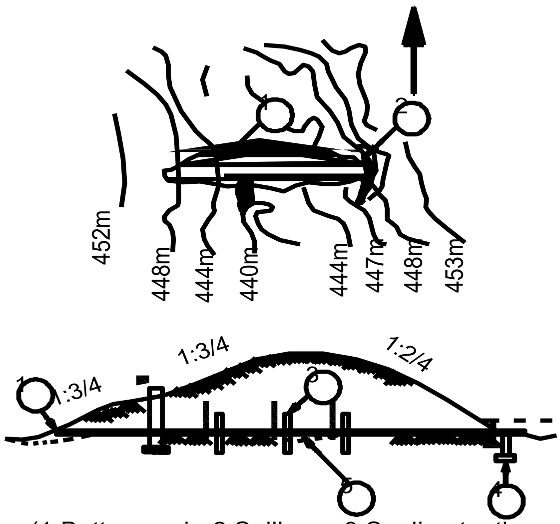



Figure 2. Flood Channel (B)

### 7.3. Flood Trap

These are small dams, typically ranging in height from 10 to 20 meters, designed to temporarily retain floodwaters and thereby reduce peak flood discharges in downstream areas. They are generally constructed without gates, and one or more bottom outlets function as uncontrolled discharge structures, which are kept continuously open.

The maximum capacity of a debris retention basin is defined by the maximum water level within the reservoir and is limited by the discharge that can be safely conveyed by the downstream river channel (Figure 4).




(1.Bottom weir, 2.Spillway, 3.Sealing teeth, 4.Outlet support column, 5.Stud wall)

Figure 3. Flood Trap

### 7.4. Levees

A levee is an artificial embankment constructed along a river channel, either on the riverbed or along the banks, to prevent erosion and to contain floodwaters within the cross-section of the river.

Levees can be classified as follows:

- Closed Levee: A levee that does not allow floodwaters to overtop from either the upstream or downstream sides.
- Open Levee: A levee connected to a higher elevation on the upstream side to prevent overtopping, while the downstream end remains open, allowing floodwaters to enter the protected area.
- Backwater Levee: A levee extended along tributary streams to the point where the backwater effect from the main river is no longer felt.
- Transverse Levee: A levee constructed perpendicular to the river to divide the protected

area into compartments, minimizing damage in the event of levee failure.

- Ring Levee (Encircling Levee): A levee that encloses specific areas to protect them from flooding.
- Seepage Levee: A secondary levee intended to stop seepage from the main levee.
- Relict Levee (Redundant Levee): An older levee that has been replaced by a new one but is retained as an additional safety measure.
- Wing Levee: A levee constructed to alter the direction of floodwater flow (Figure 5).

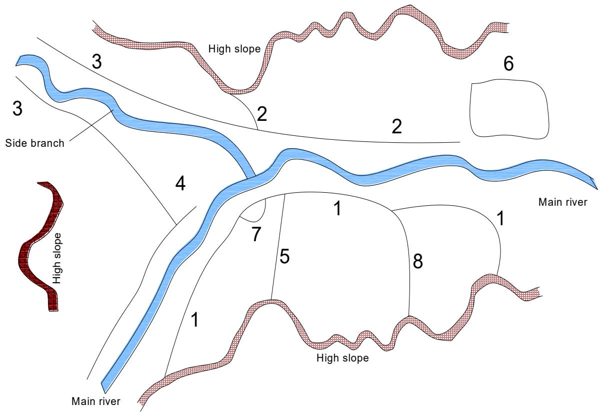



Figure 5. Classification of Levees

In some cases, levees are further classified as follows:

- Summer Levee: A levee designed to protect agricultural lands from flooding only during the plant growth season.
- Winter Levee: A levee whose crest is planned 0.5 to 1.2 meters above the maximum flood level. This is referred to as the main levee, and its implementation is considered complete levee protection.
- Contiguous Levee: A levee whose inner slope is a direct continuation of the riverbank surface, with no designated floodplain between the levee and the river channel (Figure 5).
- Detached Levee: A levee designed with a designated floodplain between the river channel and the levee itself (Figure 6).

Potential Negative Effects of Levee Construction:

- Although levees are essential for flood protection, in some cases they may lead to adverse effects on river dynamics and surrounding environments:
- The natural retention of floodwaters within the valley is eliminated.
- Water levels within the river channel may rise.
- The peak discharge of flood waves may increase.
- Flow velocity and shear stress within the floodplain can intensify.
- Agricultural lands may be deprived of nutrient-rich sediments (silt).
- Groundwater recharge from flood flows may be reduced, leading to decreased base flows.
- Sediment deposition may occur in wider floodplain areas.
- Accumulated sediments can elevate floodwater levels, eventually necessitating the raising or upgrading of existing levees.

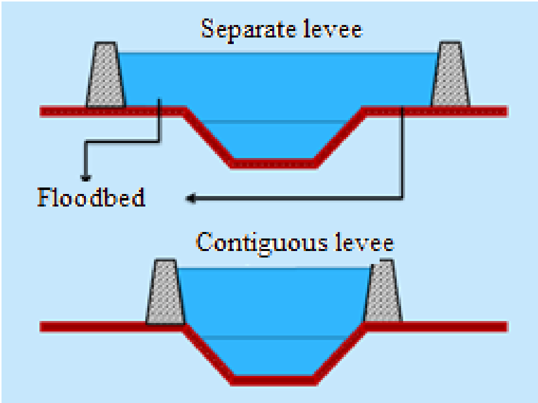
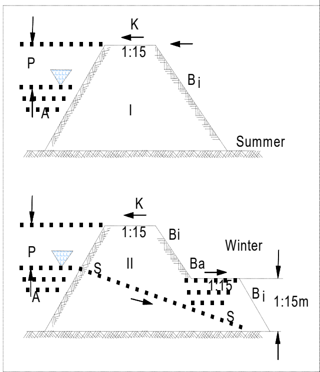



Figure 6. Contiguous (Top) and Detached Levee (Bottom) on floodplain

Separate levee
Contiguous levee
Floodbed
In general, levees are designed with a trapezoidal cross-section and constructed using homogeneous earth fill. The dimensions of the levee vary depending on its intended purpose, the characteristics of the foundation soil, and the properties of the fill material used (Figure 7).




| | Symbol | Winter bank | Summer bank |
|---|---|---|---|
| Inner slope | A | 1/2-1/4 | 1/3-1/4 |
| Outer slope | Bi | 1/1.5-1/2 | 1/5-1/10 |
| Crest widthi (m) | K | 2.5-4.0 | 1-2 |
| Free board | P | 0.5-1.2 | 0.3-0.6 |
| Shoulder | Bi | 3.5-4.0 | - |
| İnfiltration line slope | S | 1/5-1/8 | 1/3-1/5 |

Figure 7. Design Criteria for Levee

Levees are generally designed based on floods with a 50-year return period. To prevent damage during larger flood events, special emergency spillways are provided at app-ropriate locations. The slope along the levee alignment is selected to match the water surface slope of the river during flood conditions (Figure 8).

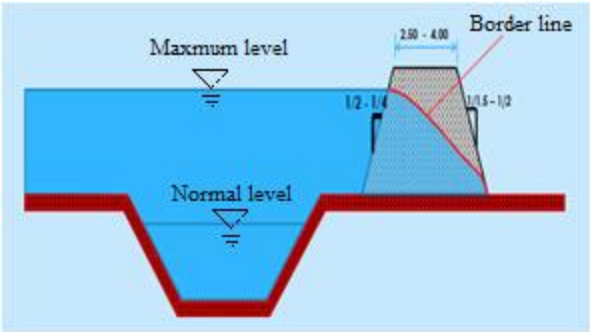



Figure 8. Levee Design

The seepage line within the embankment is the primary factor in determining levee dimensions. If the seepage line extends outside the levee, a berm on the outer slope or a permeable toe drain made of high-permeability material may be considered.

In cases where the levee fill material is highly permeable, impermeability can be ensured by applying a surface lining on the outer face or by incorporating a central impermeable core. To collect and safely discharge seepage water, a drainage ditch parallel to the levee is recommended.

Common failure mechanisms in levees include:

- Overtopping,
- Piping,
- Saturation of the embankment,
- Foundation erosion, and
- Slope instability on the outer faces (Figure 9).
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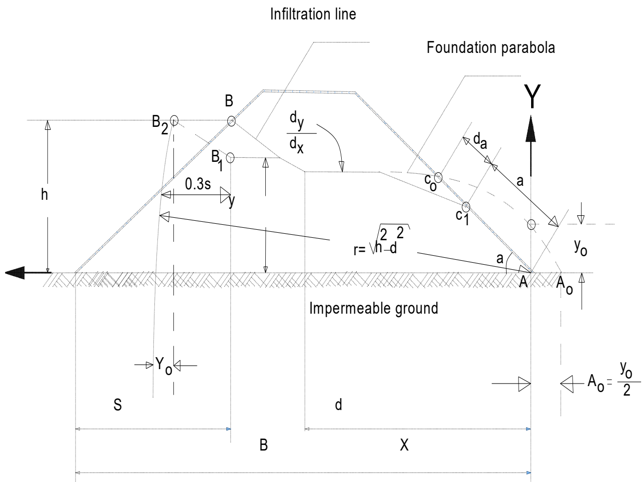


Figure 9. Seepage in Levees

In densely populated areas where land is highly valuable, flood walls are constructed along river corridors to confine floodwaters within the channel (Figure 10).

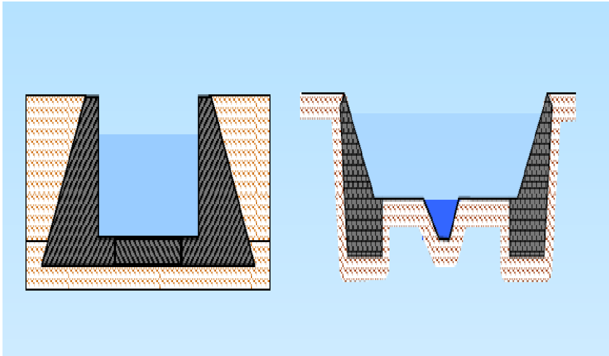

Figure 10. Flood wall

## 8. Conclusion and Recommendations

Due to the rapidly changing socio-economic structures around the world, the necessity of addressing flood risks has become increasingly evident. In the design of flood protection structures, it is crucial to understand the flood characteristics of rivers, particularly during the planning of economic analyses, flood damage assessments, and zoning regulations. Identifying the regions where flood protection structures are most needed allows for the implementation of necessary precautions before any loss of life or property occurs.

The design of flood protection or control structures requires careful consideration of river gradient, geological investigations, discharge capacity, and cross-sectional characteristics. The type of construction materials to be used should be selected to maximize cost-effectiveness. In Turkey, flood protection works carried out by the State Hydraulic Works (DSİ) are implemented both in urban and rural areas. These projects are often designed to enhance agricultural land use and to create landscape areas. However, it has been observed that such developments can have negative impacts on natural ecosystems. Therefore, it is essential that these projects are implemented appropriately and in a manner that minimizes harm to the environment.
Moreover, special attention should be paid to the following issues:

- Excavation waste and similar materials should not be dumped into streambeds.
- Instead of closed channels, open channels that are easier to clean and maintain should be constructed.
- Residential areas should not be developed in low-lying or depressed regions near rivers, canals, or streambeds; zoning plans must be implemented based on flood recurrence discharges.
- Forested areas should be expanded, land should be terraced, and afforestation should be carried out to reduce runoff and soil erosion.

- Check dams, reservoirs, or retention ponds should be constructed on rivers to capture sediment.
- Necessary infrastructure should be developed for the diversion of excess water.
- Underground sewer and wastewater drainage systems should be built with large capacity, and their outlets should not discharge directly into seas or river basins.
- Drainage systems should be installed on roads, streets, and bridges to prevent water accumulation.

As with earthquake preparedness, a state of alert and readiness must be maintained. Emergency response teams should be equipped with an adequate number of water pumps, vacuum trucks, and rescue boats, and comprehensive intervention scenarios should be developed in advance.

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