Geog Notes

Chang Si Yuan

September 25, 2016

(ver 0.1.0a)

This compilation of notes are meant to be used as a reference for the GCE "A"-level Geography Paper, focusing on descriptions of processes, case studies and exam strategy. These notes are meant for free, public use, but at the reader's own risk.
Good luck with your exams.

1 Catchment Hydrology

Catchment Hydrology is the study of the water cycle on land. Catchments, also known as drainage basins, refer to an area of land which directs its water input into a river and tributaries. Once water enters a catchment, it travels through flows and stores before leaving the basin.

1.1 Drainage Basin Water Balance

1.1.1 Inputs

Precipitation is the introduction of water into a catchment system through rain, snow or ice from the atmosphere. Humid tropics experience high precipitation (2500-4000mm in the Amazon), evenly distributed all year round in intense storms of 10cm/hr to 15cm/hr. Arid tropics experience highly variable rainfall with less than 250mm of precipitation a year across a few concentrated storms which typically last no longer than 15 minutes with a high intensity of 5mm/min.

Ice Melt is the introduction of water into a catchment due to upstream melt in frozen ice. This is typically due to a change in climatic conditions upstream where seasonal changes raise the temperature in these regions and melt ice, after which the water is contributed to its streams.

1.1.2 Stores

Interception Storage is where water is captured by the canopy layer (comprising leaves and trees) and the litter layer (comprising dropped leaves and other biological matter). Water is introduced into the store during precipitation which enters these layers before being able to proceed, after which the water in these stores are typically lost to evaporation.

Biological Storage is where water is captured and absorbed within plant mass.

Soil Moisture Storage is where water is captured in a thin film which sticks to soil particles. Soil moisture is characterized by 3 states. In decreasing water level, right after a storm the soil is flooded and saturated with water, after which the soil loses water to percolation to achieve field capacity where water is held as 'capillary water' and finally the remaining water is lost to evaporation and to plants to achieve wilting point as 'hygroscopic water'.
The fluctuations of soil moisture storage is generally determined by the climate of the area, where humid tropics generally have soil permanently at field capacity whereas seasonally humid tropics may reach wilting point during dry seasons.

Groundwater Storage and Aquifers are the storage of water in rock formations, where water originates from percolation and is typically ejected through baseflow into channels. The water table is the boundary between aquifer and the non-saturated rock above. The level of water table is affected by:
Surface relief where the water table typically follows rises and drops in a surface.
Seasonal fluctuations which affect the total volume of water stored in the aquifer.

Channel Storage is the water that is contained within a river channel.

1.1.3 Flows

Interception is where precipitated water enters interception storage. This is affected by:
Amount of vegetation cover where different amounts of vegetation can absorb from 10-50% of rainfall.
Intensity of rain where high intensity rainfall shakes water off leaves and reduces interception storage.

Leaf Drip and Stem Flow is where interception storage (especially canopy storage) flows downwards to the ground surface.

Infiltration is the seeping of water into the soil due to gravity and capillary forces.
The texture of the soil where fine soil and alluvium are less permeable. This is affected by:
The presence of vegetation where roots and fauna tunnel passages for water, organic acids from decaying matter prevent clumping, canopy cover reduces rainsplash action which would otherwise compact the soil and vegetation provides leaf matter which can increase litter interception and retain water to be infiltrated over a longer time.
The intensity of rainfall where a low total precipitation and low intensity will maximize infiltration.

Percolation is the downward flow of intercepted water towards the aquifer below.. This is affected by:
Permeability of rock affects the rate of percolation, where primary permeability is the ability of water to pass through pores in the rock and secondary permeability is the ability of water to pass through fractures, joints and bedding planes in rock.

Throughflow is where percolated water flows laterally due to a difference in soil permeability above ground, where deeper layers of rock are less permeable due to compression or the presence of clay pans. As such, water is forced laterally and may even return to the surface through return flow.

Return Flow is the flow of throughflow back above ground to be converted into overland flow.

Baseflow is the flow of water from an aquifer to a channel through the base of a river channel.

Overland Flow occurs where water flows above ground towards a channel.

Horton Overland Flow , also known as 'infiltration excess overland flow', occurs when the rate of rainfall exceeds the maximum rate at which ground can infiltrate water away, resulting in the excess water flowing elsewhere through channels above ground.

Saturation Overland Flow occurs where the water table is raised after prolonged rainfall and causes overland flow to occur. Saturation overland flow first comprises of the return flow which is ejected above ground due to a raised water table, and secondly where rainfall occurs on areas of land which meets the water table (therefore there is 0 infiltration capacity) and is forced to flow above ground.

1.1.4 Output

River Discharge is the flow of water in a river, contributed by direct precipitation (above the river), overland flow (above ground to the river), throughflow (through the side of a river) and baseflow (from below the river). Rivers have variances in temporal distribution:

Perennial Channels are permanently occupied by flowing water and are typically found in humid tropics, due to a high water table ensuring baseflow year round.

Ephemeral Channels are typically dry except for the brief period after a storm and are typically found in arid tropics because little precipitation leads to a low water table which is unable to constantly supply a channel, therefore the water in the channel is primarily obtained from overland flow and throughflow. Water typically infiltrates downwards and also is evaporated downstream, leading to a decrease in river discharge downstream.

Intermittent Channels are seasonally occupied with water due to the distinct wet and dry seasons of a seasonal tropic.

Evapotranspiration is the loss of water as a gas, encompassing natural evaporation and plant-assisted transpiration. This is affected by:
Temperature where higher temperatures allow for more evapotranspiration.
Relative humidity which determines how much moisture can be effectively transferred to the air.
Amount of vegetation which determines the rate of transpiration.

1.1.5 Water Balance

The water balance quantifies the inputs, outputs and stores of a water cycle, where the total input (via precipitation) is translated into evapotranspiration, channel runoff and finally a net gain or loss in storage.

$$P = E + R \pm S$$

1.2 Fluvial Processes

1.2.1 River Energy

When precipitation occurs, the potential energy of water due to its high altitude needs to be expended as it travels throughout the hydrological cycle. High river energy is characterized by a large amount of discharge and a large velocity.

Discharge $Q = AV$
Discharge Q is the product of cross-sectional area A and river velocity V. Discharge in humid tropics increase downstream due to increased contribution from tributary channels while discharge in arid tropics decrease downstream due to water loss by infiltration and evaporation.

Velocity $V = \frac{1.49R^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$
Manning's equation for river velocity V relates velocity to hydraulic radius R, gradient S and friction coefficient n.

Channel Slope $S = \frac{\text{Height above sea level}}{\text{Channel length}}$
Steeper slopes have a higher S value than more gradual slopes and hence have a more concentrated change in potential energy of water.

Coefficient of Rougness n
Coefficient of roughness increases as channels are rougher, typically ranging from 0.010 to 0.050. This accounts for variances in channel material and amounts of sediment.

Hydraulic Radius $R = \frac{\text{Cross sectional area}}{\text{Wetted Perimeter}}$
Hydraulic radius accounts for the surface area of the channel, where a larger surface area in contact with water implies greater frictional forces of the channel wall and bed on the fluid and hence reducing velocity. The maximum hydraulic radius of a river is of a semicircular cross-sectional area and one of a larger total volume as well.

River energy tends to increase downstream in humid tropics because as the total discharge increases due to tributaries, the hydraulic radius R increases as larger volumes of water are now more efficiently transported. Over long periods of time, the river reaches an equilibrium between its gradient and its sediment load, where now less energy is needed downstream since sediments and surfaces undergo attrition and abrasion and more energy is available to transport load due to a reduction in friction, therefore the river will achieve a concave profile.

Increases in R and decreases in n account for the reduction in S in a graded river. Therefore the river velocity still tends to increase downstream.

Urban planners design drainage channels with high R and low n in order to ensure high V in their drains to drain away water as fast as possible.

1.2.2 Erosion

Erosion is the gradual wear of a surface. Erosion in a channel takes place by 4 main mechanisms.

Hydraulic Action is the wear of a rock surface from the impact of fluid on the rock.

Abrasion is the wear of a rock surface from the impact of moving sediment on the rock.

Solution is the dissolution of a rock surface due to chemical reaction with fluid.

Attrition is the wear of sediments due to mechanical impact of sediment on sediment.

1.2.3 Sediment Transportation

Sediment transport is the process where static sediments are put into motion. These sediments are supplied from landslides and sometimes are carried with overland flow into the river during storms. Sediments are eroded when the river energy is sufficient to maintain their motion, otherwise known as when the river velocity meets the critical erosion velocity of the specific sediment size.

Sediments in a river, once eroded, are transported in the river channel by numerous mechanisms.

Traction is where sediment rolls along the channel bed.

Saltation is where sediment bounces along the channel bed.

Suspension is where sediment is suspended in turbulent flow.

Solution is where sediment is chemically dissolved in fluid.

River capacity describes the volume of sediment which a river can transport and grows with the third power of river velocity. River competence describes the largest diameter sediment that can be transported as bed load and grows with the sixth power of river velocity.

Sediment transported downstream tend to increase in volume due to the increased discharge and also decrease in caliber due to attrition and the reduction in gradient which supplies less energy to transport sediment.

1.2.4 Deposition

Deposition is the processes where sediment is taken out of transportation and remains in a static position in the river channel. Deposition takes place when there is a sudden input of load which causes the overloading of the river, such as after a landslide, or where there is a sudden loss of energy such as at a convex bank of a meandering river, at the mouth of a river or when discharge is reduced after a lack of precipitation.

River deposits typically are found on the channel bed (especially at the aftermath of a flood or storm), at the edge of the channel or on a floodplain.

1.2.5 Hjulstrom Curve

The Hjulstrom Curve is a plot of the critical erosion velocity (CEV) and the settling velocity (SV) of sediments against the diameter of a sediment. Both axes are logarithmic in scale.

The graph of CEV is a bitonic graph with a minimum at sediments of 5mm diameter. Smaller sediments are held together by strong electrostatic chemical bonds which require higher velocities to set into motion and are also small enough to be shielded by the layer of laminar flow at the bottom of a channel. Larger sediments are heavier and require more energy to be suspended.

The graph of SV begins at 0.5mm and increases sharply from diameter 0.5mm to 10mm, from which it increases gradually. Sediments smaller than 0.5mm are assumed to be permanently suspended in fluid due to their small mass, and will not settle unless the river experiences a sharp decrease of velocity at a river mouth or a lake. Sediments larger than 10mm require larger amounts of energy to be kept suspended and hence have an increasing SV.

1.3 Properties of River Channel Morphology

1.3.1 Drainage Density

The drainage density Dd of a basin is the sum of channel lengths divided by the area of the basin. A more branched basin with many tributaries has a higher Dd than one of the same area with one primary channel. Dd values range from 5km per square km on sandstone to 500km per square km on clay badlands.

Dd is useful to calculate the spacing and concentration of channels in basin and is an indicator of basin runoff which can lead to phenomena like floods.

Dd is affected by:

Long-term changes , whether a river is yet to achieve equilibrium or as a river is able to undergo headward erosion.

Rock Type of the basin which affects infiltration rate.

Total Precipitation which determines the amount of water in the channels.

Vegetation which further impacts infiltration rate.

Dd values may be inaccurate due to seasonal fluctuations of channel lengths in a seasonal tropic and also because of artificially small channel lengths due to the presence of underground limestone channels which cannot be measured sufficiently.

1.3.2 Graded Rivers and Equilibrium

Graded time is in the scale of tens to hundreds of years. Graded time allows for long-term changes in a system to occur. River morphology is the consequence of a graded river, as opposed to a quick-reacting system which responds to floods and precipitation in a matter of days or weeks.

River channels are in a balance of generating energy as water moves towards sea level and expending energy through erosion (vertical and lateral) and sediment transport. In graded time, a river is able to modify its channel slope to create a dynamic equilibrium of the two.

1.3.3 Arid Tropic Channels

Channels in arid tropics decrease in discharge downstream due to the significant infiltration of water in the channel. Arid climates also experience low surface infiltration rates which increase its drainage density and lead to the formation of wider rivers.

Channels in arid tropics typically are flat and shallow with coarse sediment, and often form braided rivers.

Channels in arid tropics have increased erosion rates due to a lack of vegetation holding its banks together.

1.4 Variations in River Channel Morphology

1.4.1 Plan Form Variations

The plan form of a channel is the top-down view of a channel, which can range from straight to meandering to braided, which generally develop due to variances in discharge and sediment load.

1.4.2 Meandering Rivers

Meandering rivers are channels whose sinuosity ratio exceeds 1 to 1.5.

Meanders form by:

1. Pools with deeper topology and finer sediment and Riffles with higher topology and coarser sediments form in straight channels as a result of varying levels of discharge, leading to a lopsided relief in a river channel.

2. A thalweg (fastest path of water flow) forms which passes through the pools and is deflected by riffles.

3. The asymmetrical flow of the thalweg leads to a corkscrew-like helicodial flow which results in high velocities at river banks near to the thalweg and low velocities at banks farther from the thalweg. Helicodial flow moves such that it contacts the concave banks while flowing downward.

4. High velocity near concave banks lead to increased erosion by hydraulic action, forming a river bluff and eroding the concave bank outwards.

5. The loss of energy to eroding the concave bank as well as the friction faced when dragged across the channel bed results in a lower velocity at the convex bank which is low enough to deposit sediment, leading to the formation of point bars and extending the convex bank.

6. Further erosion and deposition leads to the development of a meander.

7. Extended meanders can possibly erode away the ridge between two meanders, which suddenly reduces the sinuosity ratio and eventually leads to the formation of an oxbow lake.

1.4.3 Floodplains

Lateral accretion occurs when there is sufficient deposition at a meander's convex bank which eventually leads to the formation of a point bar which merges with the floodplain, therefore extending the floodplain.

Vertical accretion also occurs when meandering rivers are flooded and bankfull discharge onto the floodplain carries sediment which is deposited onto the floodplain to grow the floodplain vertically and also form natural levees around the main channel.

1.4.4 Braided Rivers

Braided rivers are channels which have solid landforms in the middle of a channel, leading to a branched network of channels which split and merge within a small distance.
Braided rivers form by:

1. Having coarse bank material which cannot maintain a large gradient, leads the the formation of a river with a large width to depth ratio (i,e. very wide and shallow).

2. Variations in discharge, in either seasonal tropics or in arid tropics, allow for sediment transport to occur during wet seasons and deposition to occur during dry seasons. Once combined with a supply for coarse sediment (whether from channel bank or elsewhere), mid channel bars begin to form.

3. During wet seasons, coarse sediment is eroded from the banks and transported to the middle of the channel.

4. During dry seasons, coarse sediment is deposited in the middle of the channel, forming mid channel bars.

5. Further sediment transport deposits more sediment onto the growing bar which disrupts channel flow and diverts it by splitting the channel in two.

6. Splitting of the channel leads to more lateral erosion of the banks of a channel, widening the channel system and migrating the anabranches outwards.

7. Decreases in channel water level will eventually expose the point bar in the channel, leading to the formation of a braided river.

8. Further vegetation can settle on the bar and make the bar more stable.

1.4.5 Long Profile Variations

The long profile of a river channel is the description of its slope with respect to its channel length.

1.4.6 Headward Erosion

Headward erosion is the erosion of a river bank which extends a section of the river upstream.

Headward erosion at springs occur as hydraulic action is concentrated at the point of spring as water forces itself out from underground aquifers onto the surface, leading to a gradual headward recession. This form of headward erosion increases drainage density.

Headward erosion at waterfalls occur as steep vertical drops in a channel lead to concentrated hydraulic action on the channel bed at a specific point, forming a plunge pool which undermines the face of the waterfall, ultimately leading to collapse of rock overhangs and the recession of a waterfall.

1.4.7 River Rejuvenation

River rejuvenation is the process at which a sudden environmental change, usually tectonic or climatic, leads to a increase of river energy and therefore a modification of its long profile.

2 Flooding in the Tropics

2.1 Hydrographs

Hydrographs are plots of river discharge at a specific cross-section of a river against time since a storm.

2.1.1 Structure of a Hydrograph

A hydrograph consists of the following:

Rising Limb is the section of the hydrograph with a positive gradient, indicating an increase in flow.

Peak Discharge is the peak of the hydrograph which indicates the maximum flow after a storm.

Lag Time is the time difference between the instant of highest precipitation and peak discharge.

Receeding Limb is the section of the hydrograph with a negative gradient, indicating a decrease in flow.

Stormflow is the area under the hydrograph which arises due to water arriving from overland flow, direct precipitation and tributaries.

Baseflow is the area under the hydrograph which arises due to water entering from the water table.

2.1.2 Comparing Hydrographs

Hydrographs with steep limbs, short lag time and a high peak are considered to be flashy. Floods which occur as a result of storms with flashy hydrographs hence lead to the term 'Flash Floods', typically referring to floods which last no longer than 6 hours. Hydrographs with more gentle limbs, longer lag time and a lower peak are considered to be attenuated.

Hydrographs can also have varying levels of discharge before and after a storm. Hydrographs that do not have any discharge before and a long time after the storm can be considered as ephemeral or intermittent.

2.1.3 Factors Influencing Hydrographs

Location of Storm where gauging stations further from the source of precipitation tend to have a more attenuated hydrograph and a longer lag time than stations closer to the source of precipitation.

Vegetation causes a more attenuated hydrograph due to interception and biological storage reducing the total discharge into rivers and also increases the amount of baseflow due to increased interception rates.

Type of Precipitation affects the flashiness of a hydrograph. High intensity rainfall create more flashy hydrohgraphs when comparing between arid and humid tropics. Large amount of rainfall among different humid tropics also lead to flashier hydrographs.

Type of Climate affects the amount of water discharge from ice and snow melt, especially in catchment basins which originate from glaciers and mountains. Higher temperatures also increase the amount of water lost to transpiration, leading to more attenuated hydrographs.

Basin Morphology affects hydrographs by determining the total amount of discharge and the speed of water flow. Basins with a smaller area catch less water but more rapidly to form flashy hydrographs. Steep slopes increase channel velocity and a high drainage density also increases the speed of which water flows (since overland flow is faster than throughflow), creating flashier hydrographs.

Basin Geology affects the permeability and therefore the flows and stores of water in the litosphere. Permeable and dry soil and permeable rocks (chalk, limestone and slake vs clay, slit and granite) allow for increased interception rates and create more attenuated hydrographs, which is compounded when present in deep layers.

Human Influence Deforestation negates the influence of vegetation and tends towards flashier hydrographs. Urban development and construction decreases the permeability of ground due to the widespread use of concrete as well as channelization of drainage systems, leading to flashier hydrographs. Poor agricultural activities such as trampling and poor soil maintenance also leads to flashier hydrographs.

2.2 Flooding in the Humid and Arid Tropics

2.2.1 Causes of Floods

Precipitation causes the occurrence of floods by providing the raw increase in input to the catchment basin hydrological cycle. Periods of increased precipitation can occur due to climatic conditions (humid vs arid), temperate seasons, monsoon seasons and tropical cyclones.

> Case Study 2.1: Singapore: Orchard Road Floods
>
> Changes in weather patterns have created periods of high rainfall intensity in the June to July months, despite the conditions from the dry monsoon. Within the Orchard Road area alone, June 2010 had precipitation of more than 100mm while June 2011 had 124mm of precipitation, more than half of which in half an hour. The former was primarily due to a clog in the road's drainage system while the latter was primarily due to sheer amount of rainfall.

Snow and Ice Melt which arise due to seasonal changes in temperature cause the sudden melting of ice and snow storages which are then channeled downstream. This phenomena is commonly observed in mountain ranges where there are larger storages in frozen water, especially the Himalayas.

> Case Study 2.2: Bangladesh
>
> The combined effect of monsoon rains during the months from June to October where 80% of its annual precipitation is received, on top of occasional cyclones. Additionally, snow melt from Tibetan region and the Himalayas in later months flow from the river Ganges and the river Brahmaputra, together with additional input from river Meghna. Finally, the topology of Bangladesh also has 80% of its land mass on a floodplain. As a result, 75% of its land has been flooded at least once before and 17% of its land is flooded annually.

Volcanic Action

Nevado Del RuizVolcanic Action

Landslides can cause a sudden input of sediment into a water body and suddenly displace large amounts of water to create a flood peak.

> Case Study 2.3: Italy: Mt Vajont
>
> The Vajont/Vaiont dam was constructed in the 1960s to meet power generation needs and also as a checkpoint to manage water between downstream channels. However, as the dam was still yet to reach peak volume in 1963 a massive landslide of 260mil cubic meters of matter was injected into the water body within 45 seconds, causing a 50mil cubic meter displacement of water over the dam in a 250m high wave, ultimately leading to the failure of the dam and also the death of almost 2000 Italians.

Dam Failure occurs when constructed dams face leaks and breakages, leading to the sudden outflow of water originally stored upstream of the dam.

> Case Study 2.4: Iraq: Mosul Dam
>
> Mosul Dam is the largest dam in Iraq, located upstream of Mosul. However, it requires 24 machines constnatly pumping concrete to reinforce the dam and has been touted the 'most dangerous dam in the world'. Simulations of dam failure estimate a death toll of 500 thousand Iraqis across Mosul and Baghdad. Additional worries arise espeially due to terrorist threats and instability in the region, especially when ISIS took territorial control over the dam in 2014 and halted maintenance.

2.2.2 Intensifiers of Floods

Urbanization leads to a decrease in interception rate due to the liberal usage of concrete and similar man-made structures, causing hydrographs to be more flashy due to the larger amount of water in a channel being supplied through overland flow. Additionally, reinforcing of drainage channels and construction of new channels can also speed up drainage due to channelization, leading to a even more flashy hydrograph.

Deforestation decreases the vegetation present in a large land area, typically due to urbanization, land clearing efforts or for agriculture. However, this typically leads to the creation of flashier hydrographs due to a decrease of surface area for evapotranspiration and also the decrease in permeability of the soil, increasing the drainage density of a catchment basin and potentially leading to floods and landslides.

Agriculture

Case Study 2.5: Malaysia

Exceptionally strong Northeast monsoons in 2014 caused extensive flooding in multiple areas of Malaysia, the worst in 30 years. Precipitation up to 250mm in 24 hours led to more than 200k displaced across both peninsular and east Malaysia. The prime aggravator of Malaysia's troubled floods was blamed on excessive logging, with more than 10% of canopy cover being lost within 2 years in states that were flooded, typically to be used to sell timber ($4.58bn industry) and for oil palm plantations.

2.2.3 Impacts of Floods

Primary Impacts are the direct consequences of a natural disaster. In the case of floods, this encompasses:

- Increased sediment transport, possibly even large objects like cars and debris and also pollutant substances
- Deposition of large debris after flood
- Increased erosion, possibly damaging man-made structures like bridges
- Water inundation and damage
- Drowning and crop damage

Secondary Impacts are the indirect consequences of a natural disaster. In the case of floods, this encompasses:

- Pollution of water supply
- Disruption of electricity and gas supply
- Disruption in public utilities such as transport and food

Tertiary Impacts are the long-term consequences of a natural disaster. In the case of floods, this encompasses:

- Change in river morphology
- Destruction of wildlife habitat
- Destruction of arable land
- Poverty and economic disruption, especially tourism
- Increase in cost of living, insurance rates
- Corruption after managing relief funding.

2.2.4 Predicting Floods

Flood prediction is the statistical study of flood occurrence to obtain a probability and frequency of flooding. One such mechanism would be through studying the recurrence interval of floods, which is obtained by sorting years by the year's record daily precipitation and then plotting a best fit graph of record daily precipitation against $\frac{\text{total years considered}}{\text{placing of this year}}$. Accuracy of this frequency estimation is improved when larger data sets are obtained, optimally in a range of 500 years.

Case Study 2.6: New Orleans: Flood Prediction and Preparation

After facing Hurricane Katrina in 2005, urban planners in New Orleans had concluded that equipping the city with levees (50 were breached) and pumping stations to account for a category 3 hurricane were insufficient. Current efforts in rebuilding has accounted for the incidence of 100-year and 500-year flood.

Flood forecasting is the collection of meteorological data as an early detection system of floods. However, the use of forecasting is slightly less useful for flash floods which are undetectable long before rainfall, especially in arid regions.

Case Study 2.7: Singapore: Orchard Road Floods

150 storm drain sensors were installed in major canals to be used as a pre-warning system. However, warnings had failed before, such as in the 2011 Orchard Road floods where insufficient predictive technology failed to notify mall operators.

Hazard mapping is the modeling of floods, from which data obtained is used for urban planning and other strategies.

2.2.5 Mitigating Floods

Structural approaches or 'Hard Engineering' involve the construction of physical structures to mitigate floods.

Artificial Levees involve the construction of concrete barriers at river banks, reinforcing the strength of the bank to prevent erosion as well as increasing the height of the channel, hence increasing the threshold of bankfull discharge by increasing cross sectional area.

Case Study 2.8: Mississippi: The Great Flood of 1993

Artificial levee systems in the Mississippi were common in the late 20th century to prevent overflow into housing areas. However, 4 to 7 times the normal precipitation in 1993 was observed and was followed by a massive flood, covering a total of 830 thousand km^2, ultimately costing $20 billion USD in damages. Most of 700 privately built levees broke, on top of numerous levee breaks near cities which threatened housing, commercial and cultural areas.

Dams help to limit the flow of water at crucial cross-sections of a channel system by installing a mechanical barrier to limit water flow downstream, therefore lowering the flood peak. However, dams also lead to ecological detriments as upstream flow (for fish) is blocked, sedimentation at the upstream portion of the dam occurs and continuous maintenance may be needed.

Case Study 2.9: Yangtze China: Three Gorges

The Three Gorges dam is 2.3km wide and 185 m high and was built due to seasonal floods which would kill hundreds of thousands of Chinese while displacing many more and could potentially flood downstream cities of Nanjing, Wuhan and Shanghai. The dam is built to change the magnitude of 10-year floods to 100-year floods, and was successful in protecting cities against the 2010 South China Floods. Power generation from the dam is also sufficient to supply almost 1 20th of China's energy demands, the same as 20 nuclear plants. However, the 1.2 million displaced due to the inundation of upstream land exacerbated poverty situations in the area.

Channelization is the reinforcement and straightening of drainage systems, natural or man-made, through paving with concrete and other materials. This decreases the friction coefficient in a drainage channel and also eliminates any erosion and sediment transport in a channel, leading to a overall increase in channel velocity. This helps to channel away water as fast as possible from a urbanized area and prevent flooding.

Case Study 2.10: Singapore: Orchard Road Floods

$25k was spent on debris-trapping gates in the Stamford Canal while $26mil was spent on elevating 1.4km of the Orchard Road street in response to the 2010 and 2011 floods.

Non-structural approaches or 'Soft Engineering' involve the use of intangible solutions to mitigating floods, usually through legislation and urban planing.

Floodways

Case Study 2.11: Canada: Red River Floodway

The Red River of the North is a river system that flows through the Canadian city of Winnipeg. High seasonal rainfall in the northern region, due to the sheer size of its catchment basin, lead to occasional overflows in this river. In order to prevent floods from affecting the city, a man-made river to the east of the city zone was constructed to act as an alternative channel for water to flow by if too much discharge could flow into the city. Recent floods in 2011, 2009 and the record-breaking 1997 flood have effectively protected the city from flooding, in 1997 flood waters reached within inches of city barriers. In total, the floodway has saved Canada an estimated $75bn in prevented flood damages.

Floodplain Zoning

Building Codes

Buyout Programs

Catchment Management

Flood Insurance

2.2.6 Flood Response

2.2.7 Floods in Arid Tropics