Smart River Engineering

Chapter 1. Introduction

Sung-Uk Choi

Department of Civil & Environmental Engineering
Yonsei University

Objectives of Chapter

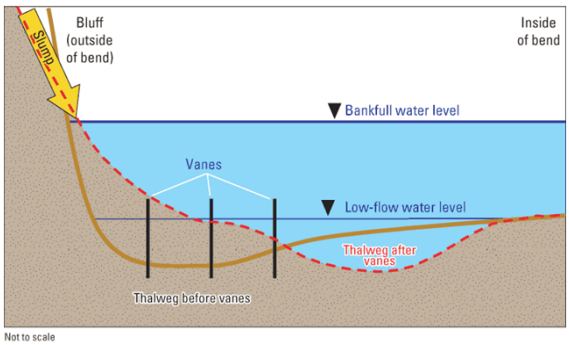
- Why is River Engineering so important?
- What type of problems do we have in River Engineering?
- What are Solution Strategies for these problems?

Introduction 1

- Majority of rivers are subject to such natural modifications as
  - meandering sand bed
  - alluvial stream
- Engineering works are to control or modify
  - discharge (or stage)
  - sediment discharge
  - stream alignment*
  - channel depth for navigation
  - floodplain for land use
  - water quality*

Stream Alignment

- Thalweg shift



- USGS Scientific Report 2004-5272
- Monitoring Channel Morphology and Bluff Erosion at Two Installations of Flow-Deflecting Vanes, North Fish Creek, Wisconsin, 2000–03

Control of Water Quality

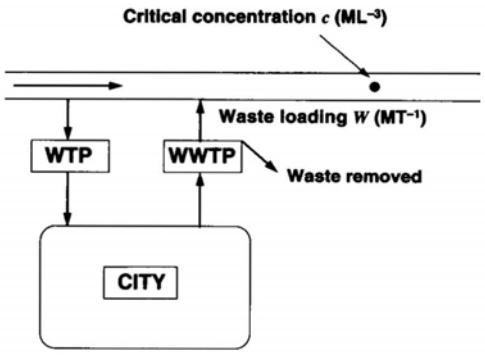


FIGURE 1.1
An urban water-wastewater system. A water treatment plant (WTP) purifi es river water for human consumption. A wastewater treatment plant (WWTP) removes pollutants from sewage to protect the receiving water.

- A significant part of the water diverted is usually returned to the stream as waste discharge.
- Some design goal has to be established that would protect the environment properly and economically.

Introduction 2

- Targets of river engineering can be summarized to
  - channelization: mostly for flood control
  - canalization: mostly for navigation

Introduction 3

- These are achieved by
  - dam and reservoir
  - levee (flood wall) and bank revetment*
  - locks* (for navigation) 갑거
  - channel contraction or dredging

Revetment: 호안공

일본 요시노강 만곡 수충부에 진행중인 호안공사
Use of close-to-nature concrete blocks for revetment in Yoshino River, Japan

Revetment: 호안공

강선으로 연결된 콘크리트 블록위에 토양이 덮여 식생이 자랄 수 있게 되어 하천의 생태를 배려한 신공법이라고 할 수 있다.
After placing the blocks, soils will be covered and grass will be grown over the soil layer.

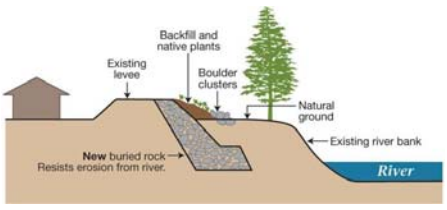
Lock

There is 15 m difference in the sea water levels in Panama Canal.

Purpose of River Engineering
(1) Flood Control and Drainage of Floodplain

- Flood control by levee*
  - may result in reduction of storage capacity of floodplain and conveyance of the river
- Increase storage capacity or diversion of flood water
  - by building a reservoir
- Increase discharge capacity*
  - reducing roughness, enlarging the cross section, and shortening the channel reach
  - However, increasing Q may result in increasing V and tractive force, which jeopardize the bank.

Levee



Missouri Army National Guardsmen patrol the top of a levee next to the flooding Mississippi River.
Joe Raedle/Getty Images

- 둑 (제방): bank, levee (하안), barrage, dike

The Great Flood of 1993 in US

On August 1st, 1993, the Mississippi River at St. Louis crested at 49.58 feet, the highest stage ever recorded.

WATERWAY – At the flood's peak on August 1, more than 1,000,000 cubic feet of water rushed past the Gateway Arch in St. Louis every second.

The size and impact of the Great Flood of 1993 was unprecedented and has been considered the most costly and devastating flood to ravage the U.S. in modern history. The number of record river levels, the aerial extent, the number of persons displaced, amount of crop and property damage and its duration surpassed all earlier U.S. floods in modern times.

After the flood

- There was a debate between the NGO and the Corps of Engineers.
- The NGO argued that what the Corps of Engineers did during the last five decades was to raise the water level.
- They raised the flood level by building the levees.
- The water level was not high even for a flood larger than this year.

- The COE countered this claim, saying previous flow measurements were not sufficiently accurate.

- What is your opinion?

River Straightening: 1989년 나주시 수해

(1) Collapse of bank

During the flood in July 1989, the bank of Yeongsan-gang River collapsed and the entire Naju city was flooded.

(2) Why it happened

The upstream part of Yeongsan Grand Bridge was strengthened, and a revetment was installed at A.

(3) Lesson

Before straightening the reach, the weak point was A. However, after the river works, the weak point moved to B. Both lab experiments and computer simulations are needed to identify the weak point.

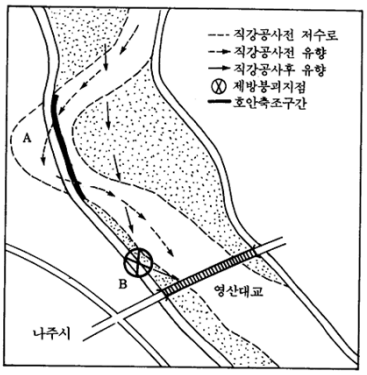


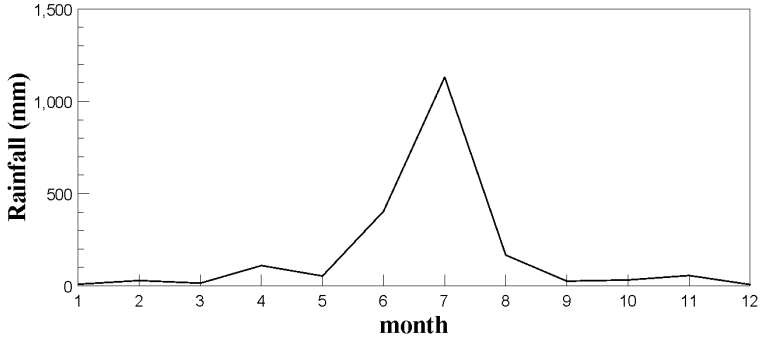
그림 4-1 1989년 7월의 나주제방 유실 상세도

Purpose of River Engineering
(2) Water Supply

• Impoundment by dam is necessary due to streamflow variability both seasonal and annual*

• Irrigation not only increases volume of food but also increases the reliability of food production (食糧資源의 武器化 대비)

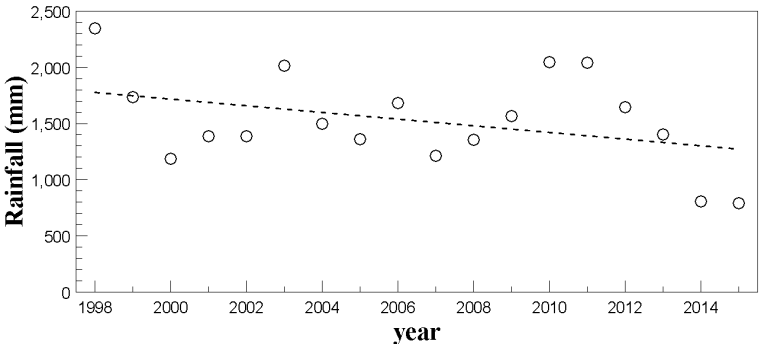
Seasonal Variability of Rainfall



Monthly rainfall in Seoul (2015)

In general, 2/3 of annual precipitation occurs in the summer in Korea.

Annual Variability of Rainfall



Annual rainfall in Seoul

Purpose of River Engineering
(3) Navigation

- Water transport is cheap but slow.
- Waterway development

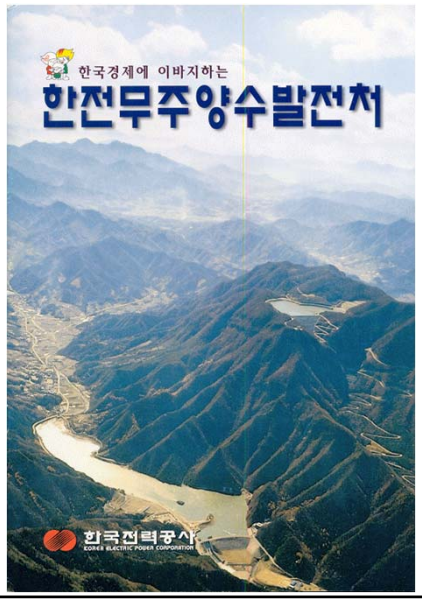
Before waterway was developed mainly for water transport, but nowadays for leisure.

Purpose of River Engineering
(4) Hydropower

- Hydropower generation has become less important, especially in Korea.
- Its role is being replaced by nuclear power plants and solar energy generation.
- Once built, it produces clean energy.
- Pumped-Storage Hydroelectricity (揚水發電)

Nuclear power plant	Fossil power generation	Hydropower generation
40%	50%	10% (8%)

Pumped-Storage Hydroelectricity



Pumped-storage hydroelectricity (PSH), or pumped hydroelectric energy storage (PHES), is a type of hydroelectric energy storage used by electric power systems for load balancing.

The method stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation.

Low-cost surplus off-peak electric power is typically used to run the pumps.

During periods of high electrical demand, the stored water is released through turbines to produce electric power.

PSH in Korea

안동 수력 발전소 (1976), 90 MW, 낙동강 (경상북도 안동시)
※ 댐식/양수발전 겸용

청평 양수 발전소 (1980), 400 MW, 북한강 (경기도 가평군)

삼랑진 양수 발전소 (1985), 600 MW, 낙동강 (경남 밀양시 삼랑진읍)

무주 양수 발전소 (1995), 600 MW, 괴목천 (전북 무주군)

산청 양수 발전소 (2001), 700 MW, 덕천강/내대천 (경남 산청군)

양양 양수 발전소 (2006), 1000 MW, 남대천 (강원도 양양군)

청송 양수 발전소 (2006), 600 MW, 길안천/용전천 (경북 청송군)

예천 양수 발전소 (2012), 800 MW, 금곡천 (경북 예천군)

무주양수발전

양수발전

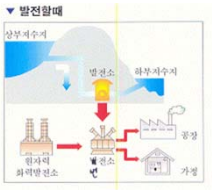
● 상부저수지(적상호)
• 댐 형 식 : 중앙 차수벽식 석괴댐
• 댐 크 기 : 높이 60.7m × 길이 287m × 체적 920,000㎥
• 만 수 위 : EL 860m
• 저수용량 : 3,486,000㎥

● 전력홍보관
전력에 관한 과거와 현재, 미래를 볼 수 있으며 전기를 유용하게 사용하는 지혜가 있는 곳입니다.

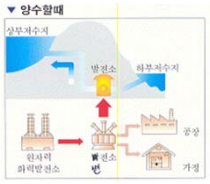
● 지하발전소
• 규 모 : 폭 21m × 높이 49m × 길이 98m
• 펠프/터빈 : 가역식 프란시스 수차
• 발전전동기 : 30만kW × 2기
• 회 전 수 : 450RPM
• 최대 유량 : 발전시 65㎥/sec
양수시 54㎥/sec
• 낙 차 : 579. 5m

● 하부저수지(무주호)
• 댐 형 식 : 중앙 차수벽식 석괴댐
• 댐 크 기 : 높이 42.6m × 길이 234m × 체적 550,000㎥
• 만 수 위 : EL 278m
• 저수용량 : 6,400,000㎥

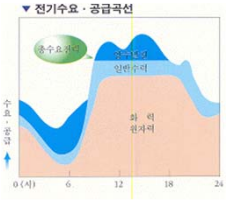
양수발전



Generate hydropower for the peak time

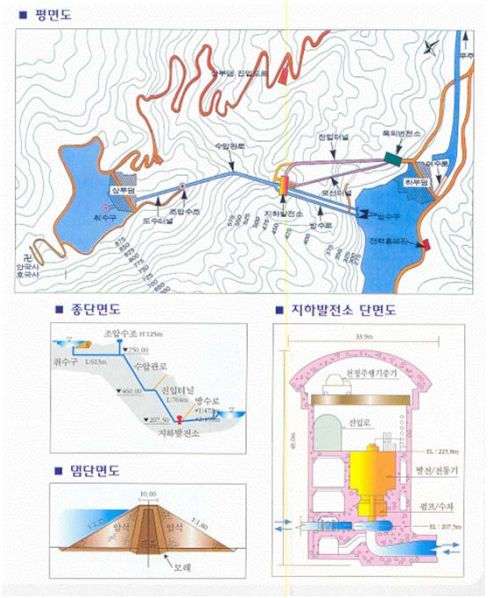


Pump water from lower reservoir for the off-peak time



Distribution of the load of generating electricity

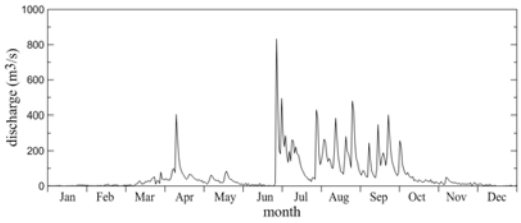
양수발전



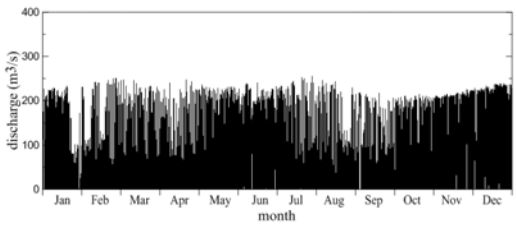
Purpose of River Engineering
(5) Cooling Water

- Downstream power plants or industries need water for cooling process.
- The amount of water required is small, but the impact of returned heated water is detrimental. Thermal shock

Hydropeaking and Thermopeaking



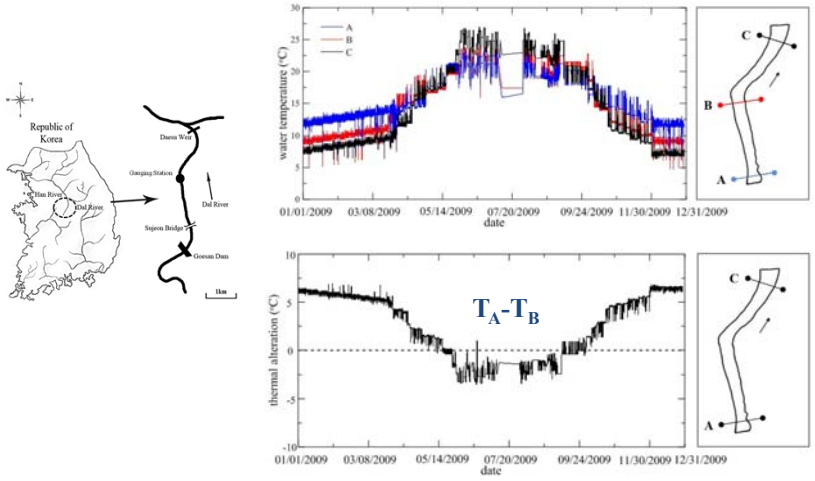
Inflows to the dam



Hydropeaking flows

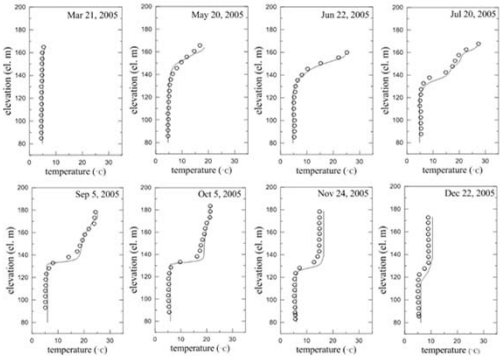
Soyang-gang Dam (2005)

Thermopeaking in Goesan Dam



The dam releases warm water in the winter and cold water in the summer.

Stratification and Cold Water Damages

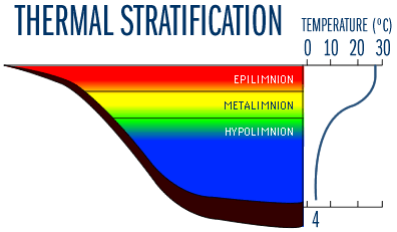


(a) Simulated and observed water temperature in 2005

Soyang-gang Dam (2005)

Terminologies

- Hydropeaking: Short-term fluctuations of flows in the reach downstream of a dam due to hydropower generation
- Thermopeaking: Short-term fluctuations of water temperature due to hydropeaking flows



수자원공사, 군남댐 급방류 임진강 생태계 파괴 논란 (2016.08.11)

Local fishermen: "Only 1/10th of the average catch after sudden discharge" Some fishermen receive daily wages and do weeding work after missing the blowfish season due to sudden discharge on May 17 Residents: "The water temperature dropped, destroying the fish habitat... "Should have released it slowly over time" vs. "We have no choice but to release it according to the manual" K-water and local governments need to jointly study the impact of sudden discharge on the ecosystem of the lower reaches of the Imjin River.

In particular, the habitat of blowfish and other fish has been destroyed as a large amount of water from Gunnam Dam, which has a temperature 7 degrees lower than that of the lower reaches of the Imjin River, has been released in a short period of time, causing poor fishing conditions for several years.

Takifugu obscurus
(blowfish)

Purpose of River Engineering
(6) Recreation

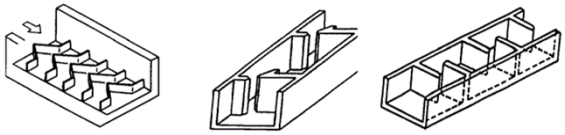
- Artificial floods in Glen Canyon Dam on Colorado River, AZ in US
- Weir removal in Korea

Artificial Floods

- When Glen Canyon Dam was completed in 1966, sand bars disappeared slowly in the reach downstream of the dam.
- This affected the business of water sports such as rafting along the river.
- In fact, they had been rafting along the river and pitching tents on the sandbar to stay overnight, but when the sandbar disappeared, they lost the place to pitch their tents.
- So, USBR decided to generate artificial floods using dams on the tributaries to supply sands to the downstream reach.

Purpose of River Engineering
(7) Fish and Wildlife

- Two issues in longitudinal continuity
- Various fishways



(a) Larinier—Denil type (b) Vertical slot type (c) Ladder type

The Denil fishway was developed in 1909 by Belgian scientist G. Denil. It uses a series of symmetrical close-spaced baffles in a channel to redirect the water flow, allowing fish to swim around the barrier.

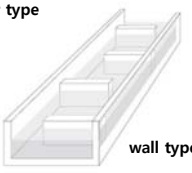
The flow turns upon itself at the base of the baffle and this creates a low velocity zone that fish use to ascend. The main advantage of Denil fishways is that they can be built on steeper slopes compared with pool-type fishways like the vertical-slot design.

Types of Fishways

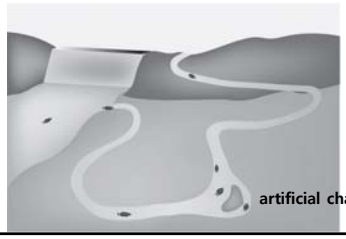
- Pool type
  - ladder type
  - vertical slot type
  - ice harbor type
- Channel type
  - wall type
  - Denil type
  - artificial channel type
- Operation type
  - lock gate type
  - lift type

ice harbor type

vertical slot type



wall type



artificial channel type

Fish Ways: 어도

일본 시코쿠 제일의 하천인 요시노강 개발사 1672년부터 치수사업을 하였다는 사실이 놀랍다. (조선조 현종)

Fish Ways: 어도

요시노강의 하구언

Fish Ways: 어도

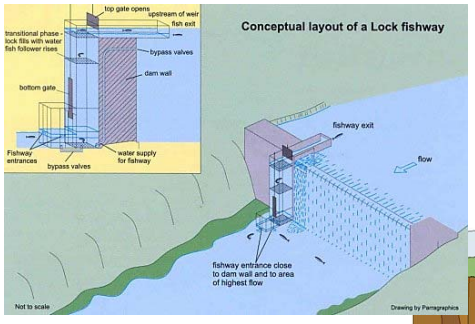
어도 크로우즈업

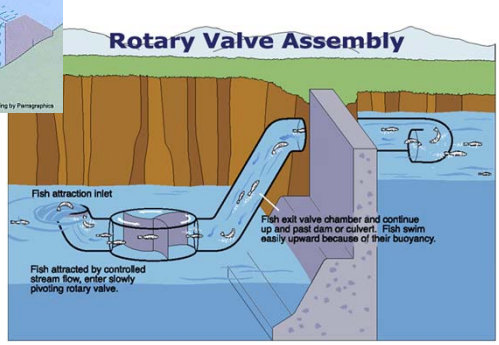
Fish Ways: 어도

콘크리트 표면의 조도를 높이기 위해 돌기를 만들어 주었다

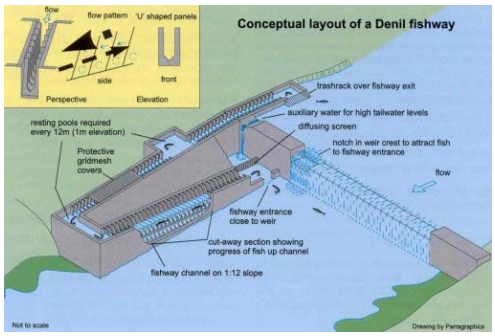
수류저항을 증대시키기 위한 시설물

Some Conceptual Fishways (1)





Some Conceptual Fishways (2)



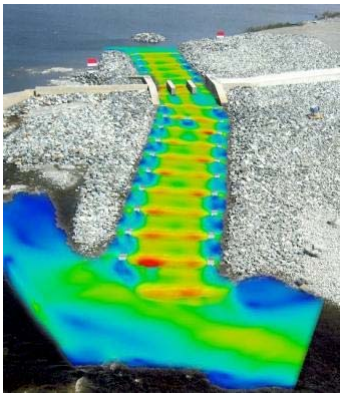
Example of Fishway (1)

Kinneytown Fishway on the Naugatuck River in Seymour, Connecticut

Example of Fishway (2)

Hadley Falls Fish Lift

CFD for Fishway



- Fishways have not been so successful, but they are highly needed.
- CFD can be used to improve the function of the fishways.