Fluid Dynamics

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Lecturer

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Education

1990, Ph.D., Civil Engineering, Univ. of Illinois at Urbana-Champaign, U.S.A.
1983, M.Sc., Civil Engineering, Seoul National University, Korea
1981, B.Sc., Civil Engineering, Seoul National University, Korea

Profession

1990~91, Research Associate, Illinois State Water Survey, U.S.A.
1992~ present, Professor, Seoul National University, Korea
2007, Visiting Professor, UC Davis, U.S.A.
2014, Visiting Professor, Colorado State University, U.S.A.

Research Interests

Diffusion and Dispersion in Surface Waters
Modeling Hydrodynamics and Contaminant Transport in Rivers
Design of Ocean Diffuser Systems
Data-based Modeling for River Flow and Water Quality

Fluid Dynamics

Course Information:

No. and Title: 457.561/Fluid Dynamics (3-3-0)

Prerequisites:

Elementary Fluid Mechanics and Lab.

Hydraulics and Lab.

Grade:

Class Participation	10%
Homework Assignments	20%
Term Project	30%
Final Exam.	40%

Fluid Dynamics

Objectives:

This course, which is a core course in the Hydraulic Engineering graduate program, deals with the advanced theories of hydrodynamics to be the basis of design and analysis of the social infrastructures such as river and hydraulic structures, dam, power plant, etc. Further, in this course, students will learn all the capabilities necessary for the modeling of the practical fluid phenomena in the river and for the analysis of numerical simulations of rivers and water resource structures.

Fluid Dynamics

Description:

This course deals with the physical concepts and fundamental equations of fluid dynamics in the advanced level. In the beginning of this course, the similarity of the fluid transport phenomena and stress-strain relations are discussed. Main part of this course will be focused on three-dimensional expressions of equations of continuity and motion for viscous fluids. Specific topics and applications in fluid dynamics are also treated. In the latter part of the course, dynamics of turbulent flow, turbulent boundary layer theory, and turbulence modeling are studied in detail.

Fluid Dynamics

Texts:

◦ Seo, I.W., Lecture Note of Fluid Dynamics, Seoul National University, 2020, Web: ehlab.snu.ac.kr

◦ Daily, J.W. and Harleman, D.R.F., Fluid Dynamics, Addison-Wesley, 1966.

◦ Kundu, P.K., Cohen, I.M., and Dowling, D.R., Fluid Mechanics, 5th Ed., Academic Press, 2012.

◦ Tennekes, H. and Lumley, J.L., A First Course in Turbulence, MIT Press, 1972.

◦ Rodi, W., Turbulence Models and Their Applications in Hydraulics, IAHR Monograph, A.A. Balkema, 1993.

Fluid Dynamics

Contents:

1. Fluid Characteristics
2. Kinematics
3. Fluid Transport
4. Continuity, Energy, and Momentum Equations
5. Stress-Strain Relations
6. Equations of Continuity and Motion
7. Boundary Layer Flows
8. Origin of Turbulence
9. Turbulent-Boundary Layer Flows
10. Turbulence Models

Weekly Schedule:

Week	Lecture (File Name/No. of Slides)	Homework
1	Ch. 0 Introduction (LC0/50) Ch. 1 Fluid Characteristics (LC1/40)	
2	Ch. 2. Kinematics (I) (LC2/26) Ch. 2. Kinematics (II) (LC3/31)	HW #1
3	Ch. 3. Fluid Transport (LC4/32) Ch. 4. Continuity, Energy, and Momentum Equations (I) (LC5/24)	HW #2
4	Ch. 4. Continuity, Energy, and Momentum Equations (II) (LC6/26) Ch. 4. Continuity, Energy, and Momentum Equations (III) (LC7/36)	**Term project title**/HW #3
5	Ch. 5. Stress-Strain Relations (I) (LC8/27) Ch. 5. Stress-Strain Relations (II) (LC9/33)	HW #4
6	Ch. 6. Equations of Continuity and Motion (I) (LC10/28) Ch. 6. Equations of Continuity and Motion (II) (LC11/23)	
7	Ch. 6. Equations of Continuity and Motion (III) (LC12/32) Ch. 6. Equations of Continuity and Motion (IV) (LC13/35)	**Term project proposal presentation**
8	Ch. 6. Equations of Continuity and Motion (V) (LC14/20) Ch. 6. Equations of Continuity and Motion (VI) (LC15/33)	HW #5
9	Ch. 7. Boundary Layer Flows (I) (LC16/27) Ch. 7. Boundary Layer Flows (II) (LC17/32)	
10	Ch. 8. Origin of Turbulence (I) (LC18/20) Ch. 8. Origin of Turbulence (II) (LC19/22)	
11	Ch. 8. Origin of Turbulence (III) (LC20/31) Ch. 8. Origin of Turbulence (IV) (LC21/37)	
12	Ch. 8. Origin of Turbulence (V) (LC22/22) Ch. 9. Turbulent Boundary Layer Flows (I) (LC23/14)	HW #6
13	Ch. 9. Turbulent Boundary Layer Flows (II) (LC24/42) Ch. 9. Turbulent Boundary Layer Flows III) (LC25/28)	
14	Ch. 10. Turbulence Models (I) (LC26/22) Ch. 10. Turbulence Models (II) (LC27/29)	
15	Ch. 10. Turbulence Models (III) (LC28/30) Final Exam	**Term project final presentation**

Term Project

A. Outline

	Proposal	Final Report
Presentation (PPT)	Week 7	Week 15
Presentation Time	5 min	15 min
PPT	PPT 6 pgs.	PPT 15 pgs.
Report	A4 2-4 pgs.	A4 10-20 pgs.

* Term Project title (English) should be submitted on Week 4.

Term Project

B. Presentation (Recommended)

(1) Title page: Presentation title and author

(2) Introduction: Issue and necessity of research, research objectives

(3) Theoretical research: Previous and current research trends

(4) Methods: Research detail and methodology

(5) Result and discussion: Analysis of research results

(6) Conclusion: Summary and conclusion

(7) References

Term Project

*** Remarks**

- Introduce significant governing equation and BC& IC only.
- Introduce significant pictures and graphs only.
- Proposal and report must be written in English.
- Refer to Hydraulic Terminology Dictionary.
- Punctuality is important in presentation (Practice in advance).

Term Project

C. Outline of Proposal and Final Report

1. Proposal

(1) Research title

(2) Necessity and background of research

(3) Objective and scope of research

(4) Research methodology

(5) Reference

Term Project

2. Final Report (Recommended)

(1) Title

(2) Abstract (including keywords)

(3) Introduction – Necessity and objective of research

(4) Body- Research trends, theoretical studies, experiment/numerical simulations

(5) Summary and conclusion

(6) Reference

* Remarks: Spacing between lines should be 1-1/2 space, unimportant pictures and graphs should be included in the appendix.

Term Project

- **Suggested Term Project Topics**

1. Commercial Software

Modeling 2-D turbulent flows using TEACH-2E

Modeling 2-D incompressible viscous flows using ELOW

Modeling hydrodynamics of flow in a river Wando using RMA2/HDM-2D/FaSTMECH

Modeling pollutant transport in a meandering river using RMA4/CTM-2D

Modeling bed deformation in a river using Nays2DH/TELEMAC2D/CCHE2D

Modeling flood in a river and floodplain using Nays2DFlood

Numerical modeling of mass transport for 2-D trench using FLUENT/OpenFOAM

Analysis of flow characteristics of dam spillway using FLUENT/OpenFOAM

Analysis of flow characteristics of dam spillway using SSIIM

(www.bygg.ntnu.no/~nilsol/ssiimwin)

Term Project

2. Numerical modeling

Numerical modeling of Navier-Stokes equation using SIMPLE method (Semi-Implicit Method for Pressure-Linked Equations)

3. Analytical study

Analytical and numerical investigations of 2-D boundary layer equation

Comparative study of turbulence models for Reynolds equation

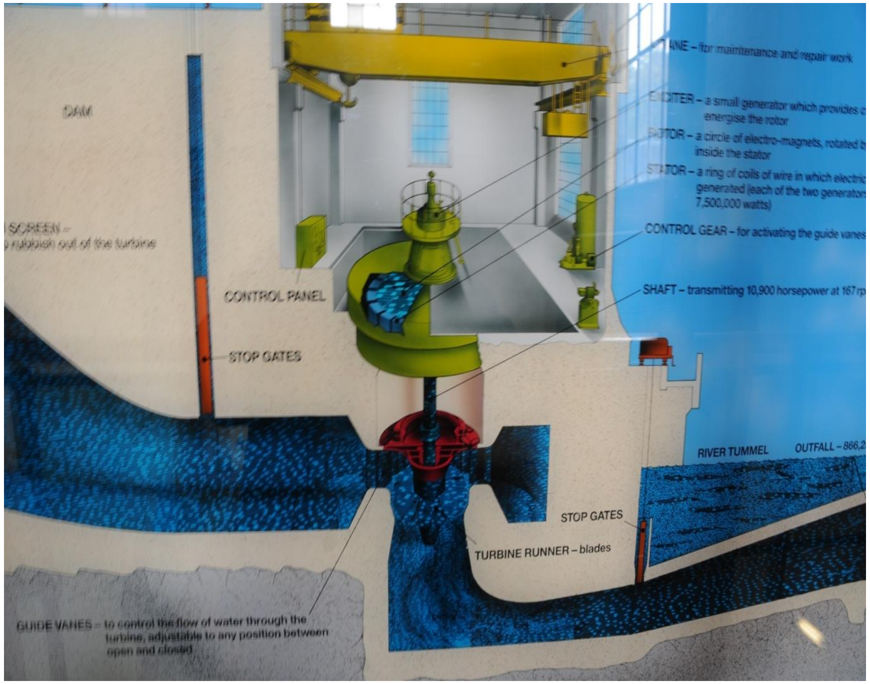
4. Experimental study

Experimental study of turbulent flow over the weir in the open channel

Experimental study of 2-D flow/pollutant transport around the weir in the open channel

Fluid Dynamics

Chapter 0 Why Fluid Mechanics?



Chapter 0 Why Fluid Mechanics?

Contents

0.1 Speculation of Leonardo da Vinci

0.2 Physics of Golf

0.3 Water Resources

0.4 Dams

0.5 Hydropower Plants

0.6 Flood Control

0.7 River Navigation

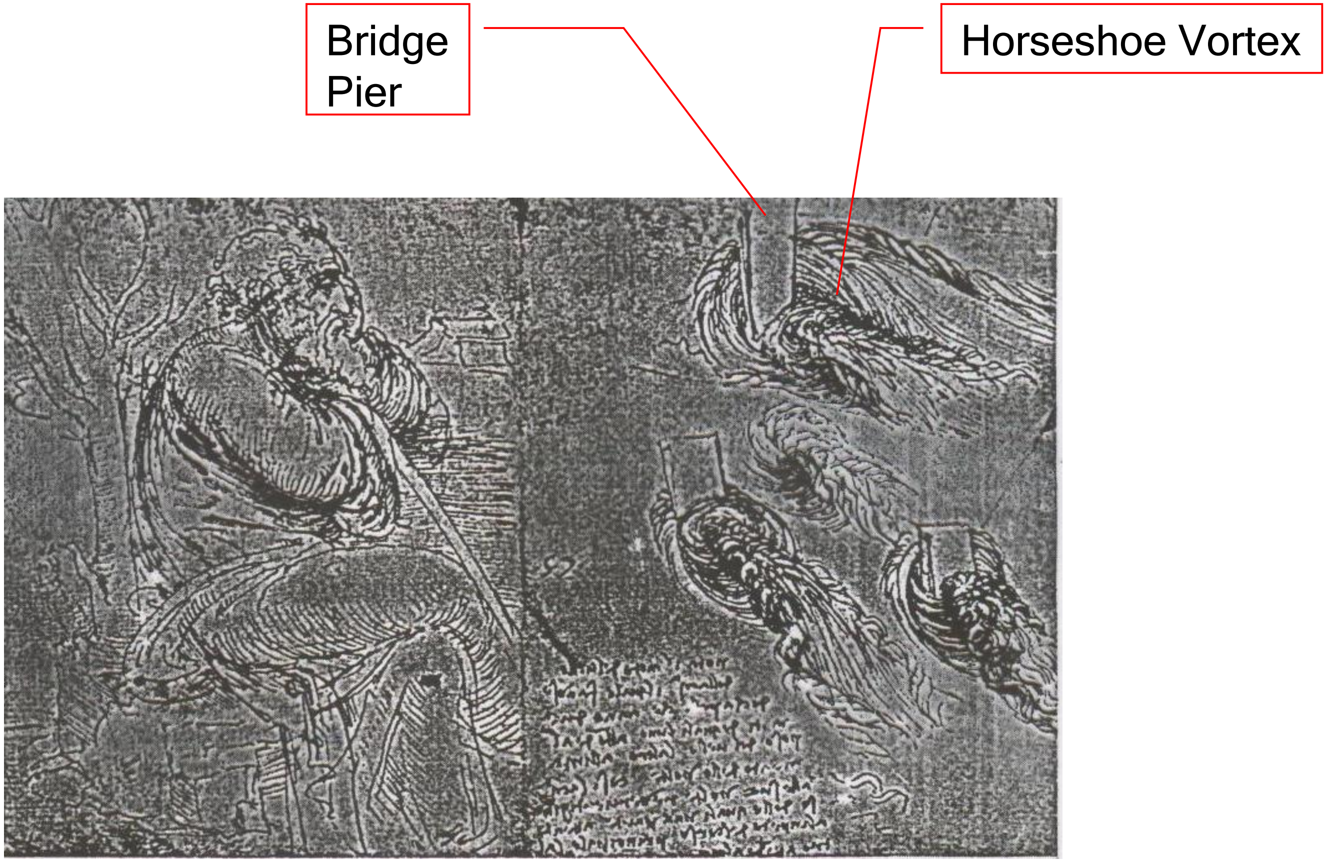
0.8 River Recreation

Chapter 0 Why Fluid Mechanics?

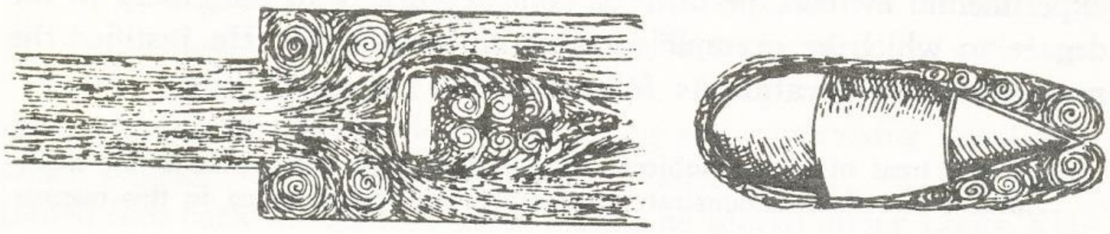
Objectives

- Find your motivation to attend this class
- Introduce practical applications of fluid mechanics

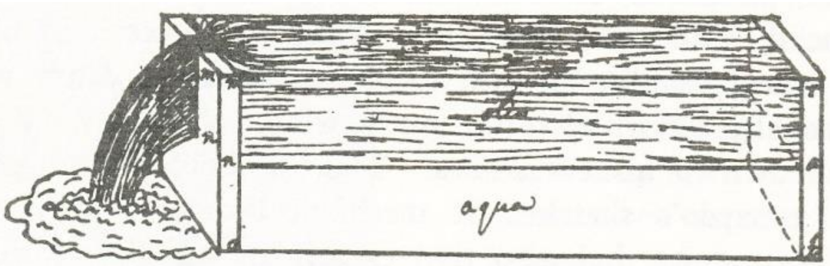
0.1 Speculation of Leonardo da Vinci



0.1 Speculation of Leonardo da Vinci



Eddy formation in zones of separation.



Sketch by Leonardo of flow over a contracted weir.

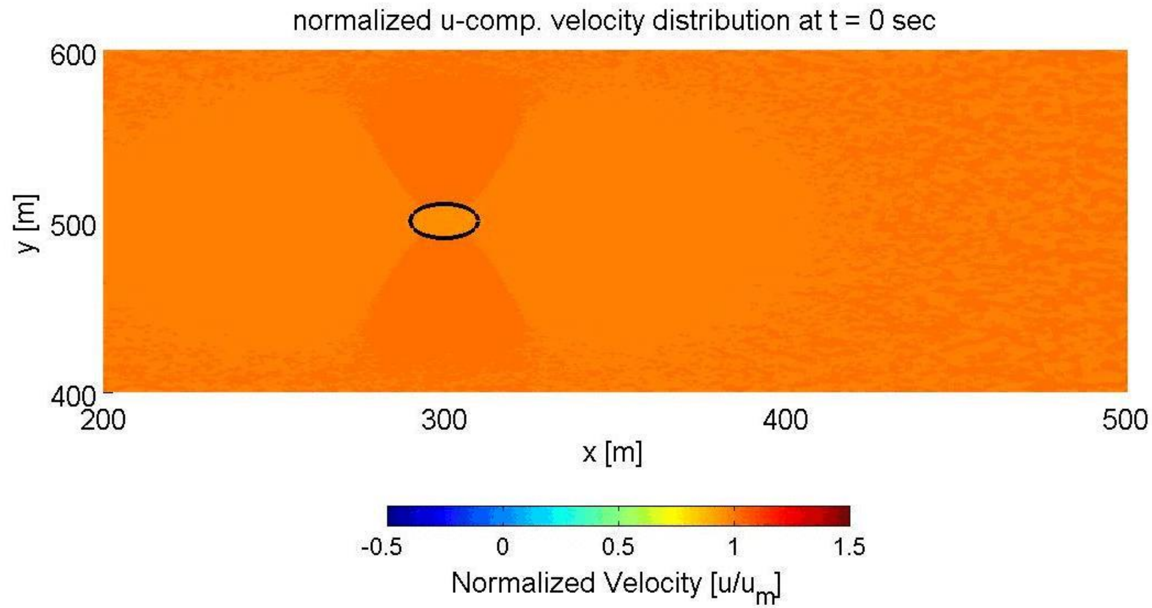
0.1 Speculation of Leonardo da Vinci

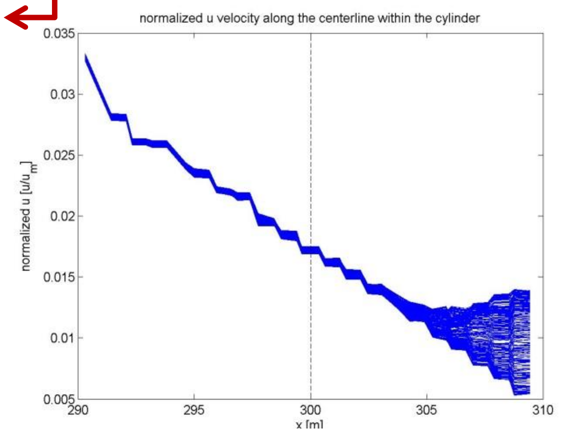
Velocity field around/within a single cylinder

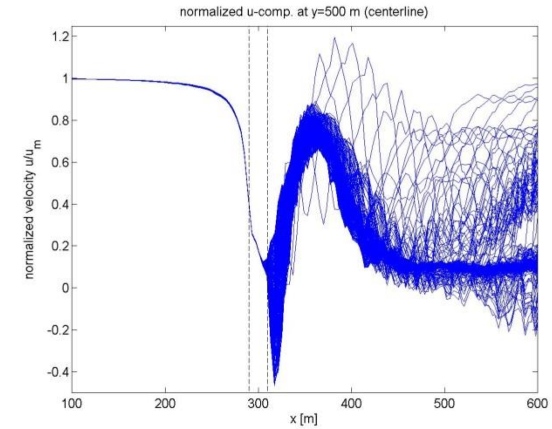
- Momentum reduction by quadratic drag law formulation.
  - Governing equations including the drag law formulation.

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -g\frac{\partial h}{\partial x} + \nu_H\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) - C_{DB}\frac{\sqrt{u^2+v^2}}{H}u + F_{D,x}$$

$$F_{D,x} = -\frac{\alpha C_D (u^2+v^2)^{1/2}}{D}u,$$



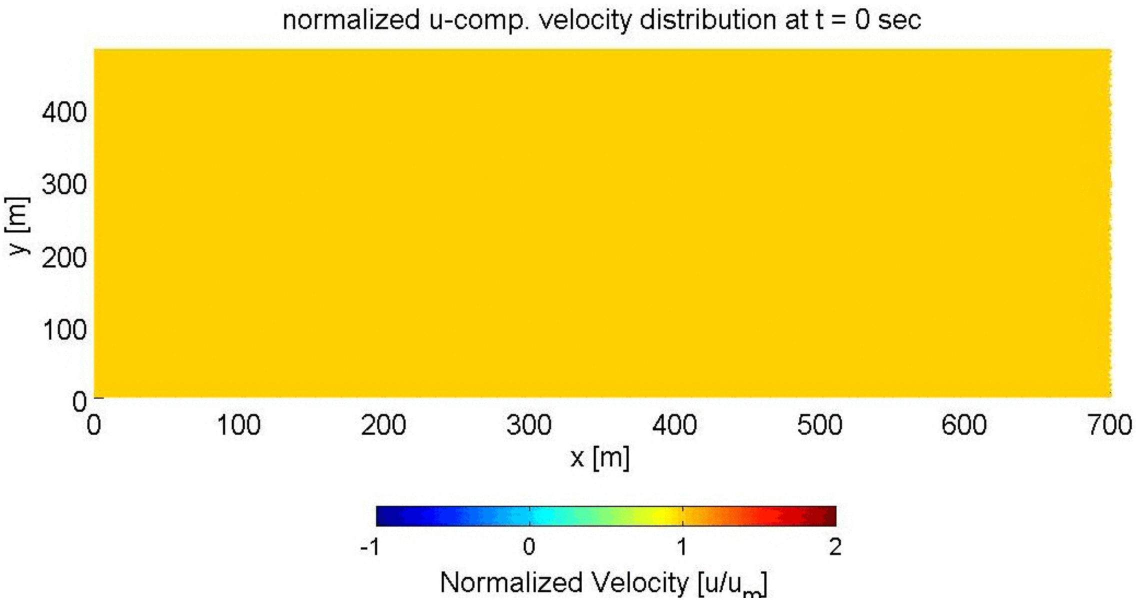




Velocity fields

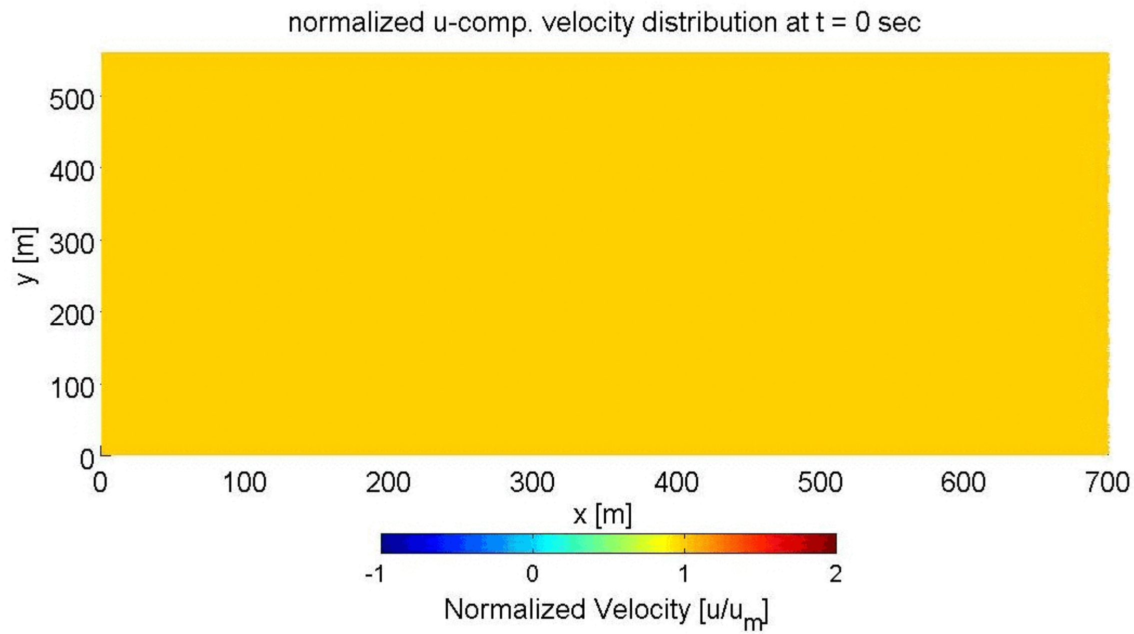
$L_G/D = 2$

$L_T/D = 2$

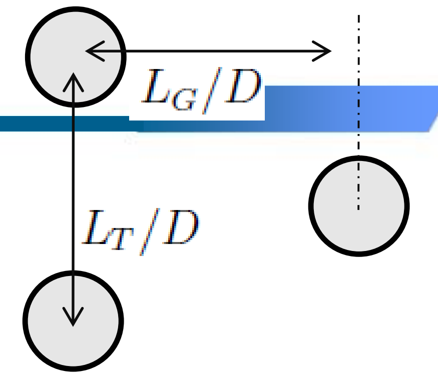


$L_G/D = 2$

$L_T/D = 4$

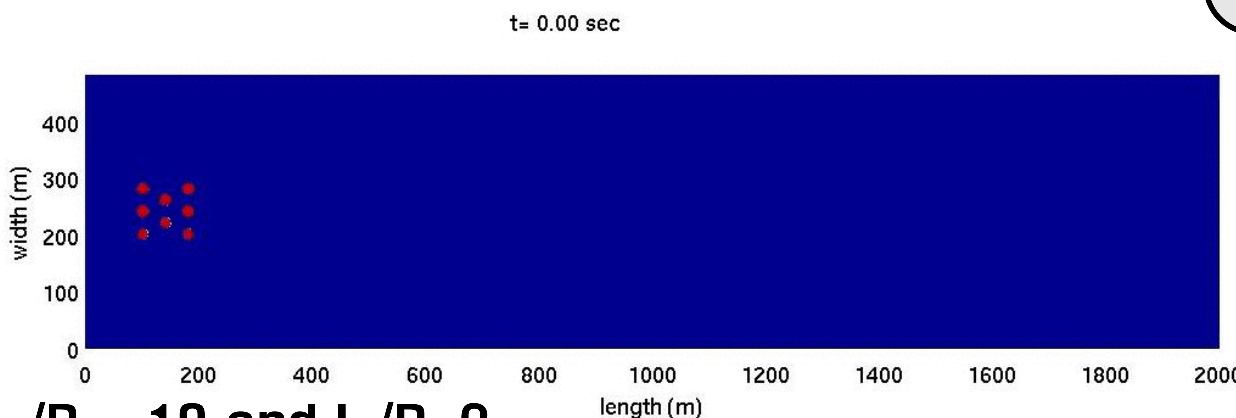


Staggered array cases

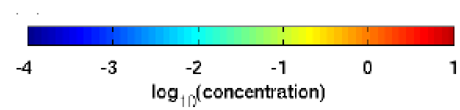


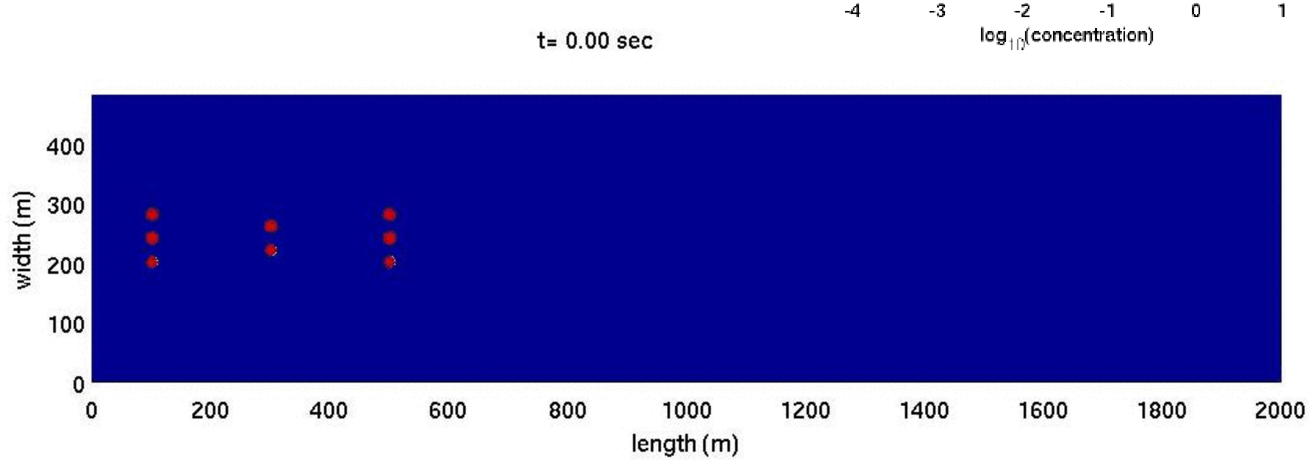
❐ Mixing around staggered arrays

– L_G/D = 2 and L_T/D=2



– L_G/D = 10 and L_T/D=2





0.2 Physics of Golf

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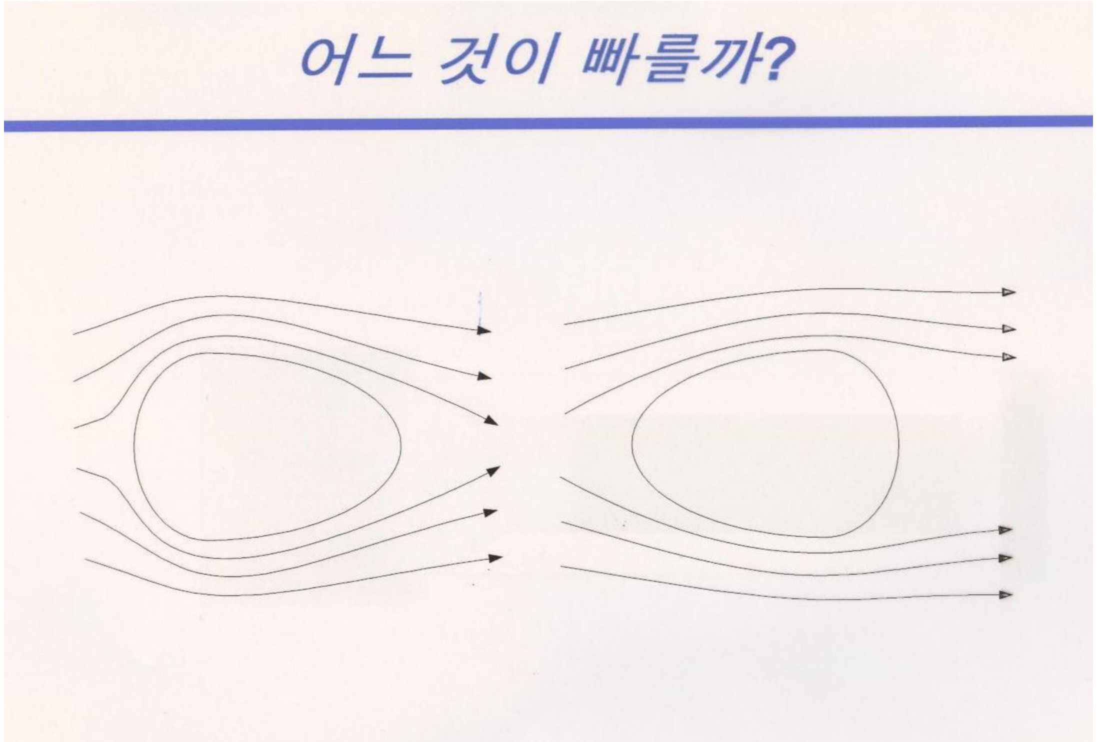
(A) (B)

0.2 Physics of Golf



0.2 Physics of Golf

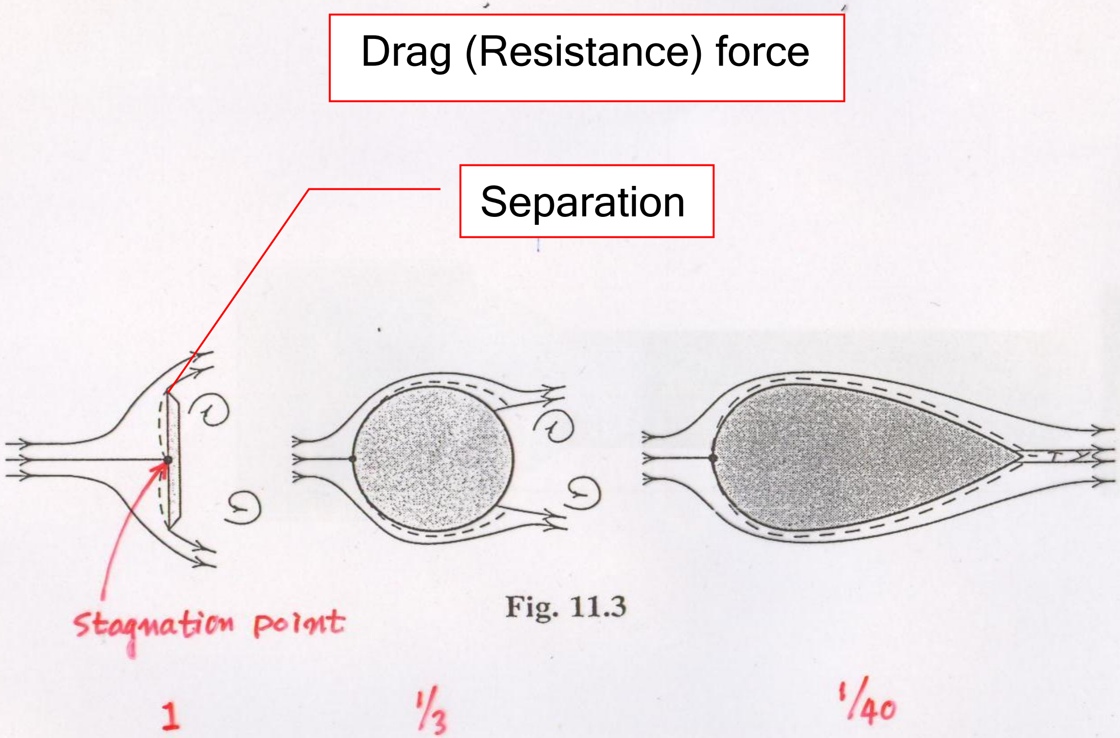
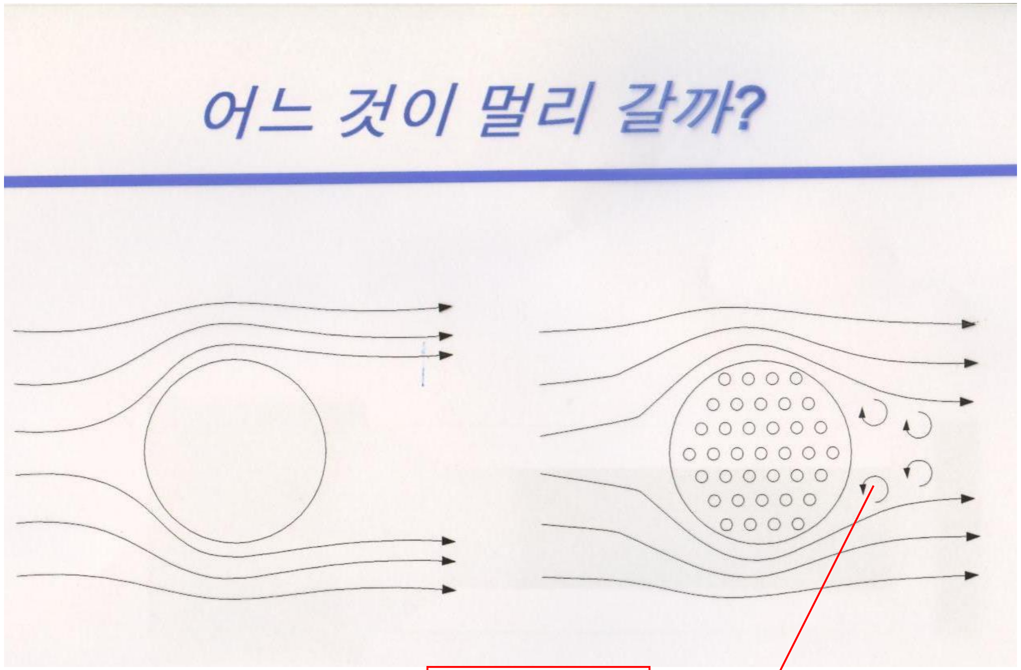


Fig. 11.3

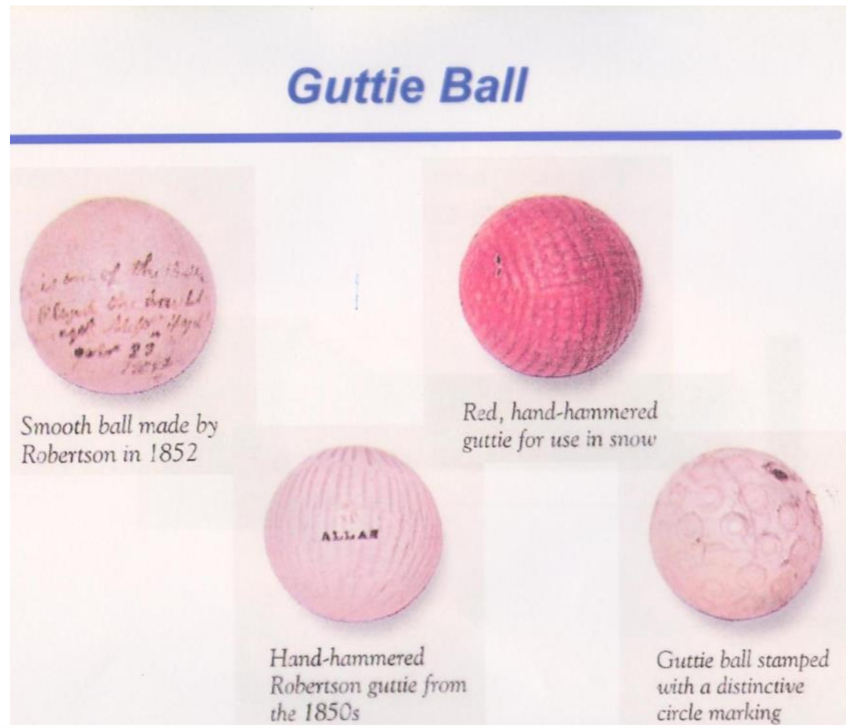
0.2 Physics of Golf

0.2 Physics of Golf



Turbulent Eddy

0.2 Physics of Golf



0.2 Physics of Golf

Rubber-core Ball

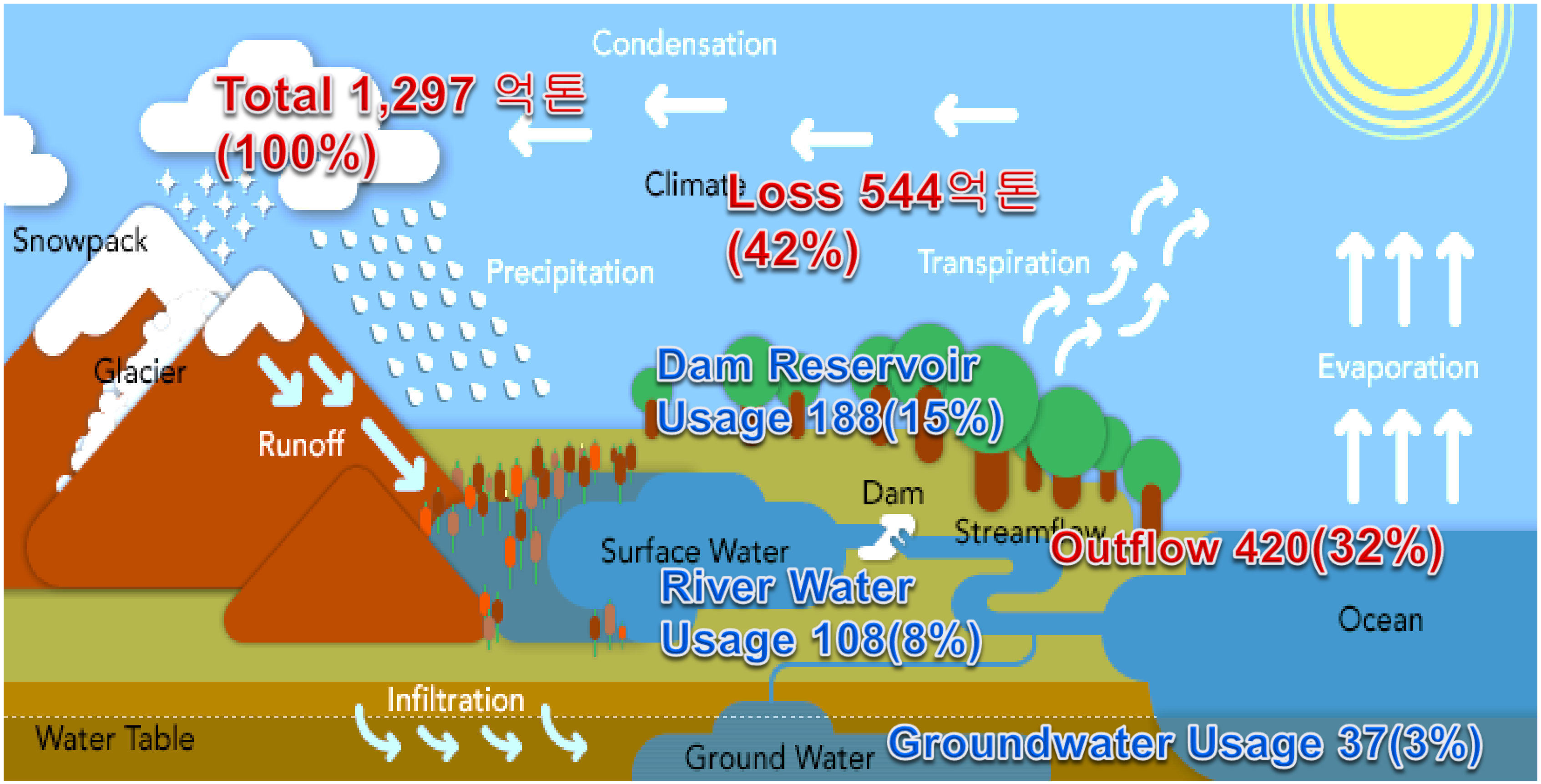
Three-piece (Surlyn Cover)

This version of the three-piece wound ball has a solid rubber core over which rubber yarn is wound for good control. The cover is made from Surlyn, a thermoplastic resin that is harder than balata and is thus considerably more durable; it is virtually uncuttable.

Three-piece (Balata Cover)

The balata-covered, liquid-centred three-piece ball might be described as the most advanced of golf balls. The wound construction over a liquid centre, combined with a soft, synthetic balata cover, produces the highest spin rate, making it the ball with maximum control and superb feel.

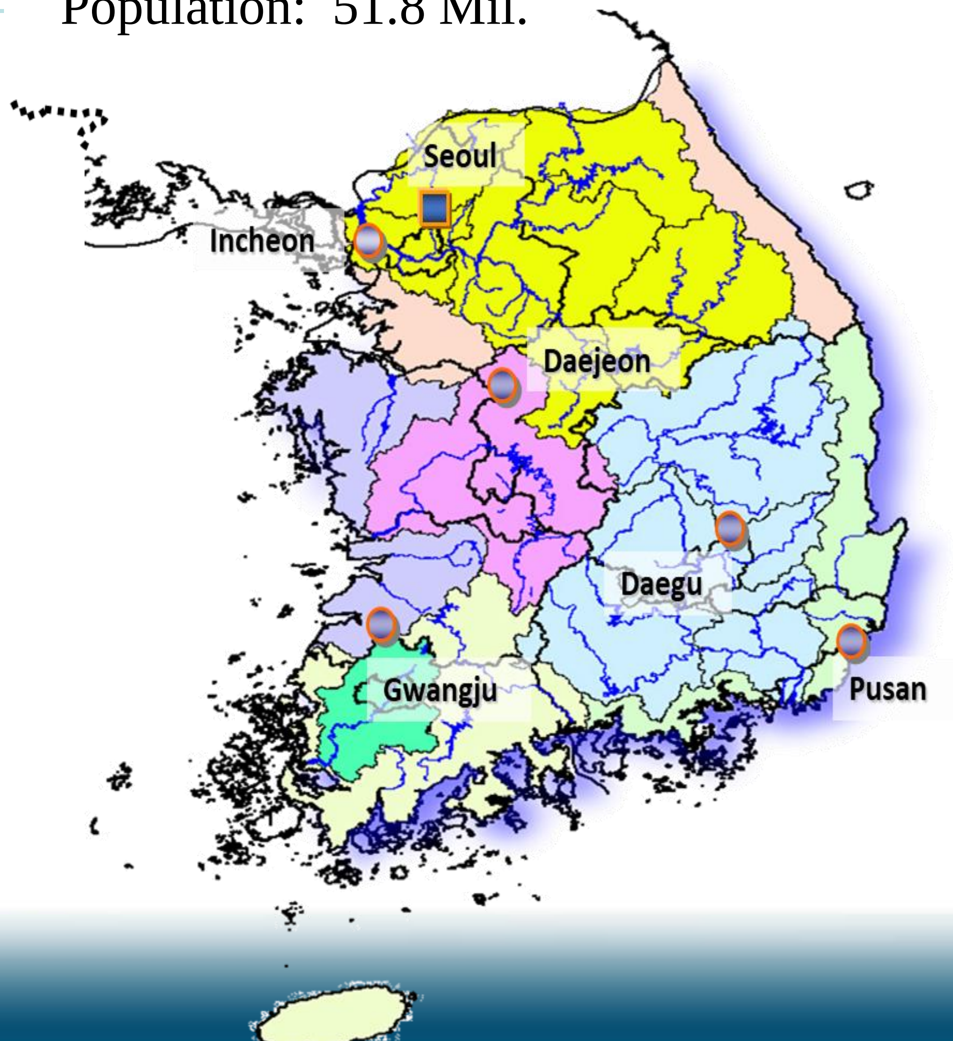
03 Water Resources



Total water usage 333억톤(26%)

Water Resources in Korea

- Annual precipitation: 1,281 mm/yr
- Land area: 99,460 km^2
- Population: 51.8 Mil.



Water Demand	억 m^3 (%)
Drinking	76 (20.4)
Industrial	23 (6.2)
Agricultural	**152 (40.9)**
River environments	121 (32.5)
Total	372

Water Supply	억 m^3 (%)
Dam reservoir	188 (56.5)
River	108 (32.4)
Groundwater	37 (11.1)
Total	333

<Minister of Environments, 2016>

0.4 Dams

<Chungju Dam>

H 97.5 m; L 464 m
Storage: 2.75 billion m^3
Power: 400,000 kW

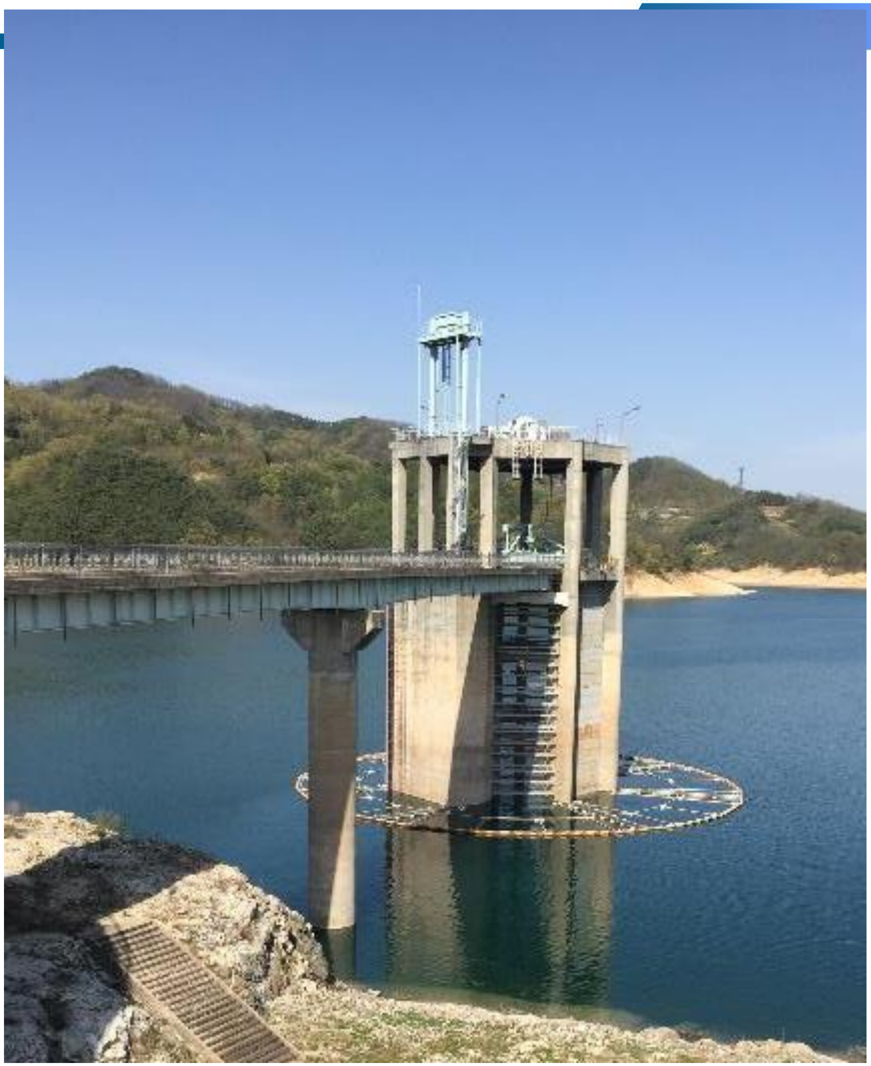
0.4 Dams

<Daechung Dam>
H 72 m; L 495 m
Storage: 1.49 billion m^3

<Soyang Dam>
H 123 m; L 530 m
Storage: 2.9 billion m^3

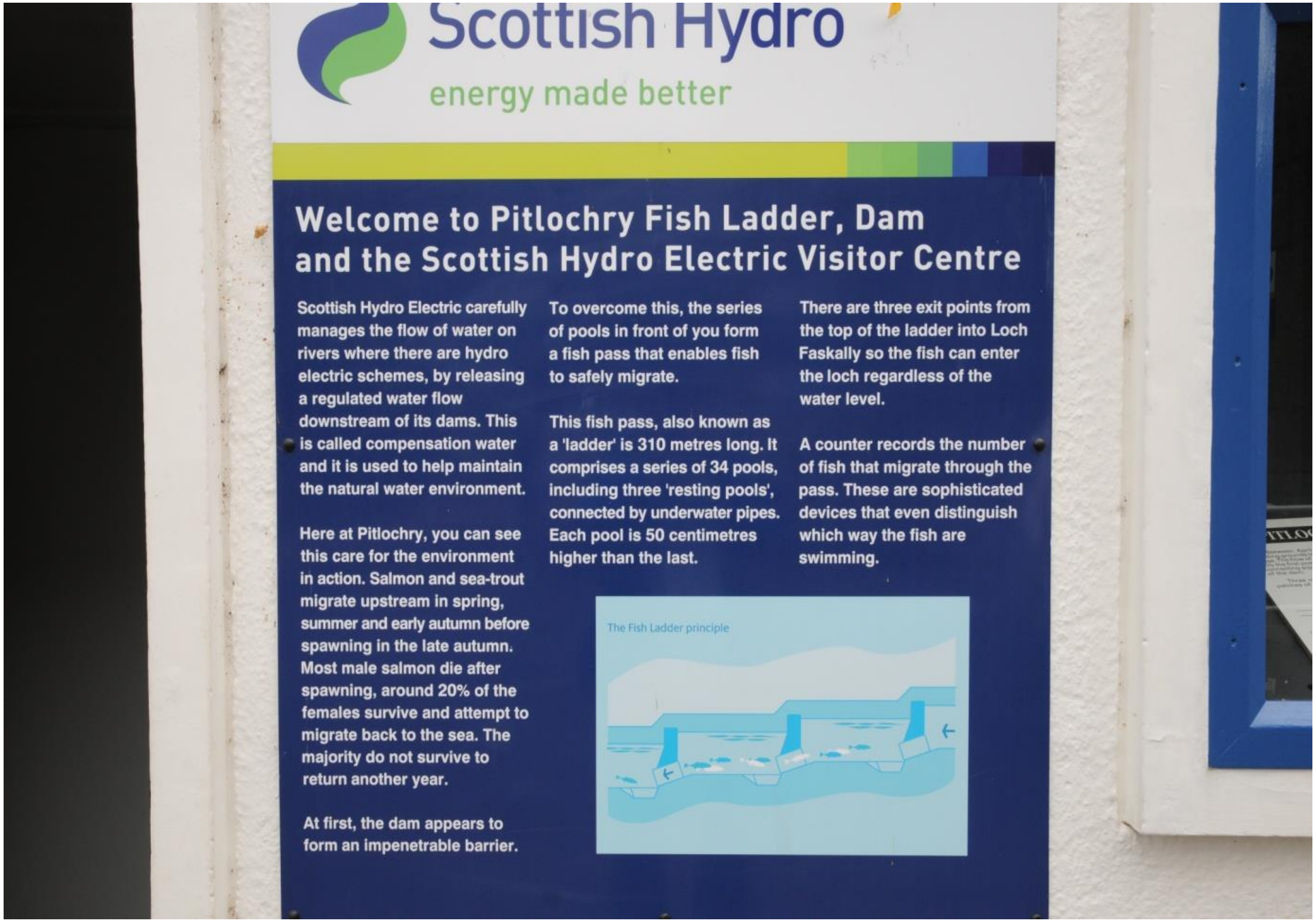
Water Supply System

Paldang dam

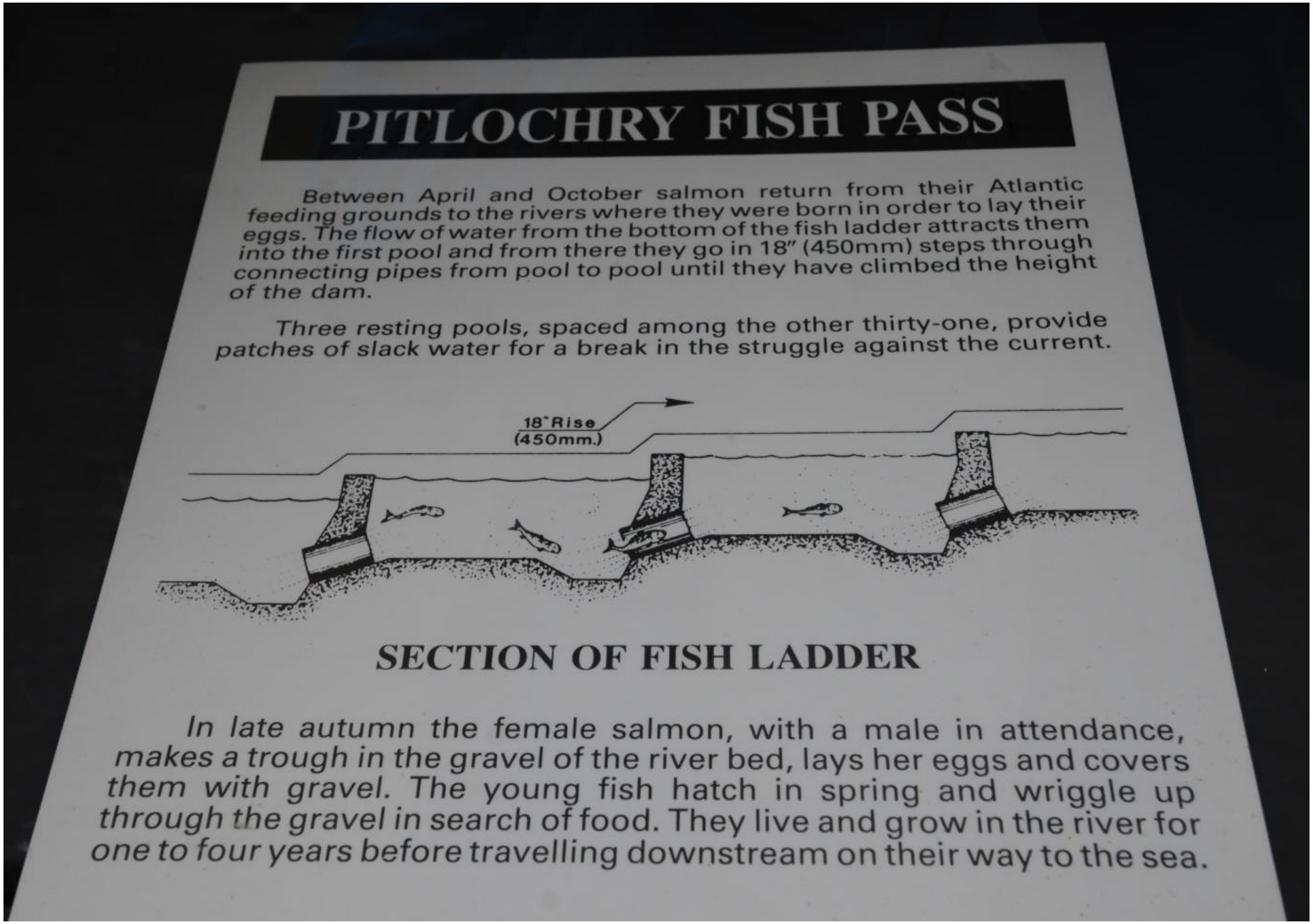


Andong dam

0.5 Hydropower Plants



0.5 Hydropower Plants



0.5 Hydropower Plants

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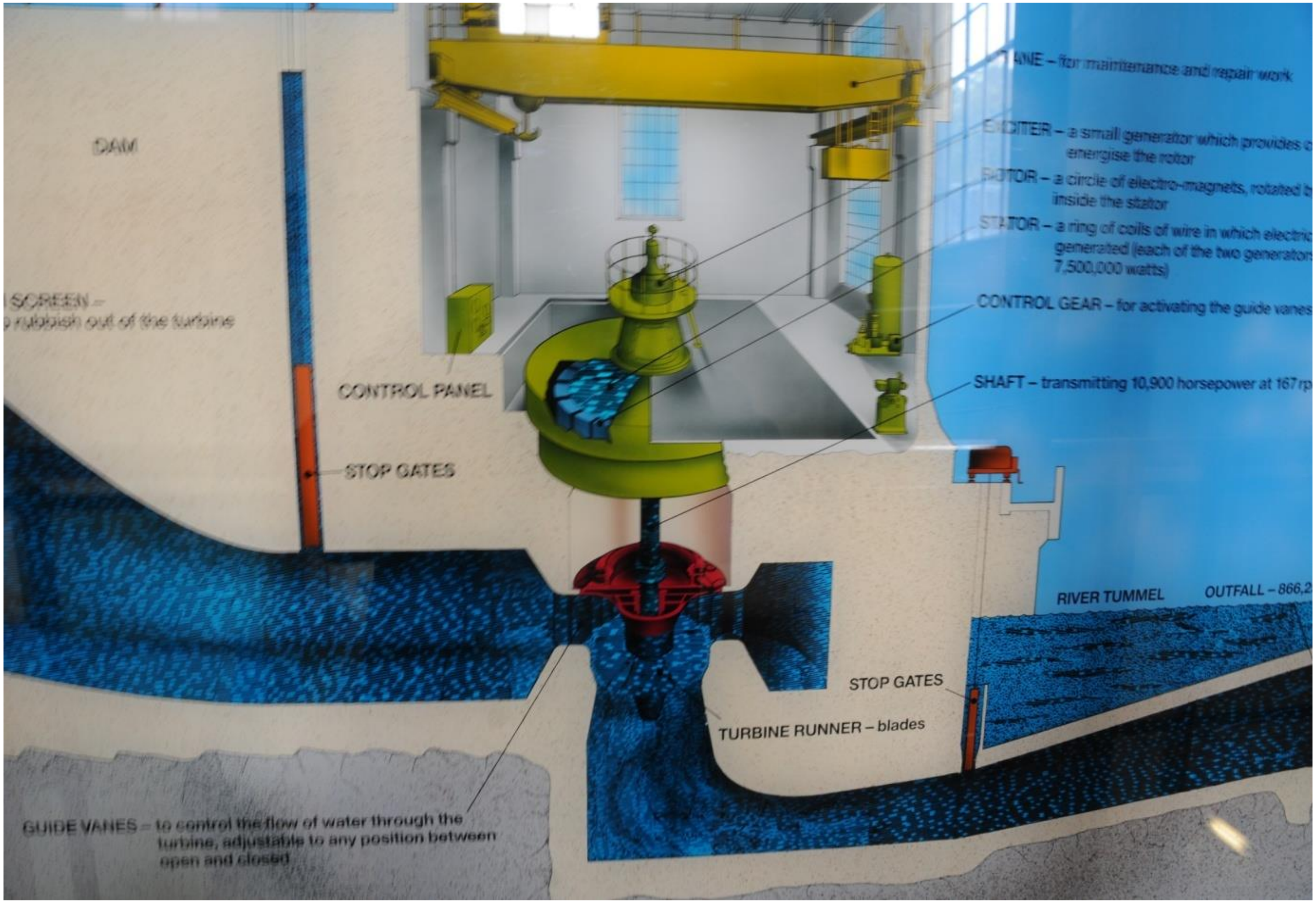


Francis turbine

<Yubari Dam>

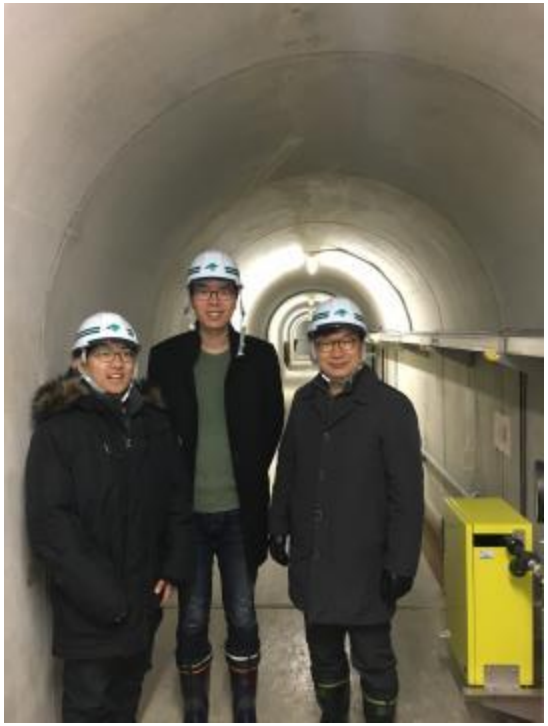
H: 110 m

L: 390 m

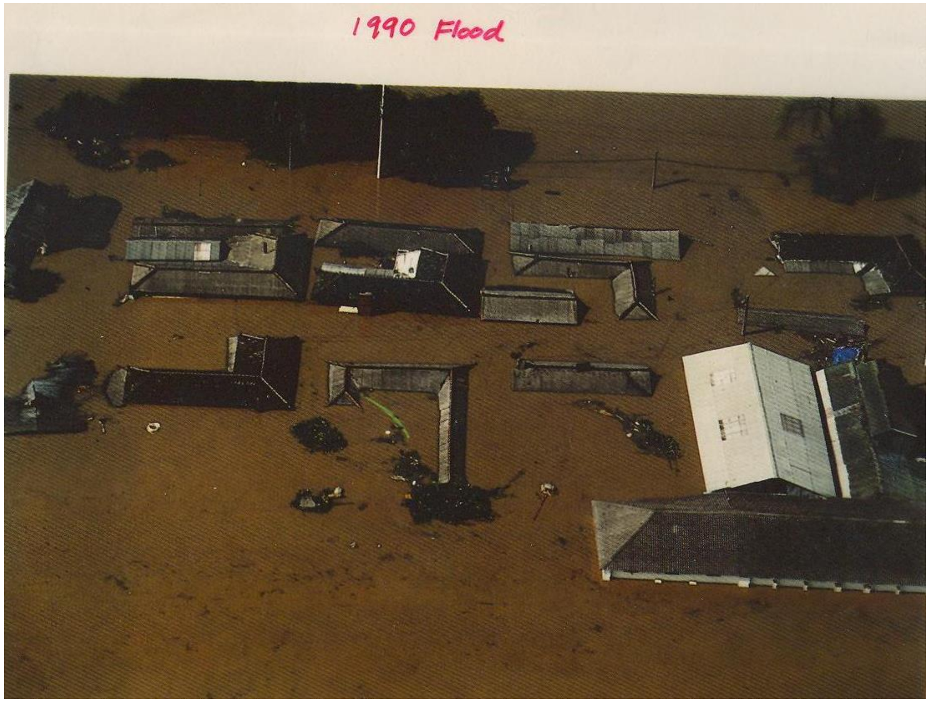
Storage: 0.43 billion m^3

Power: 26,000 kW

< Yubari Dam, Hokkaido, Japan>



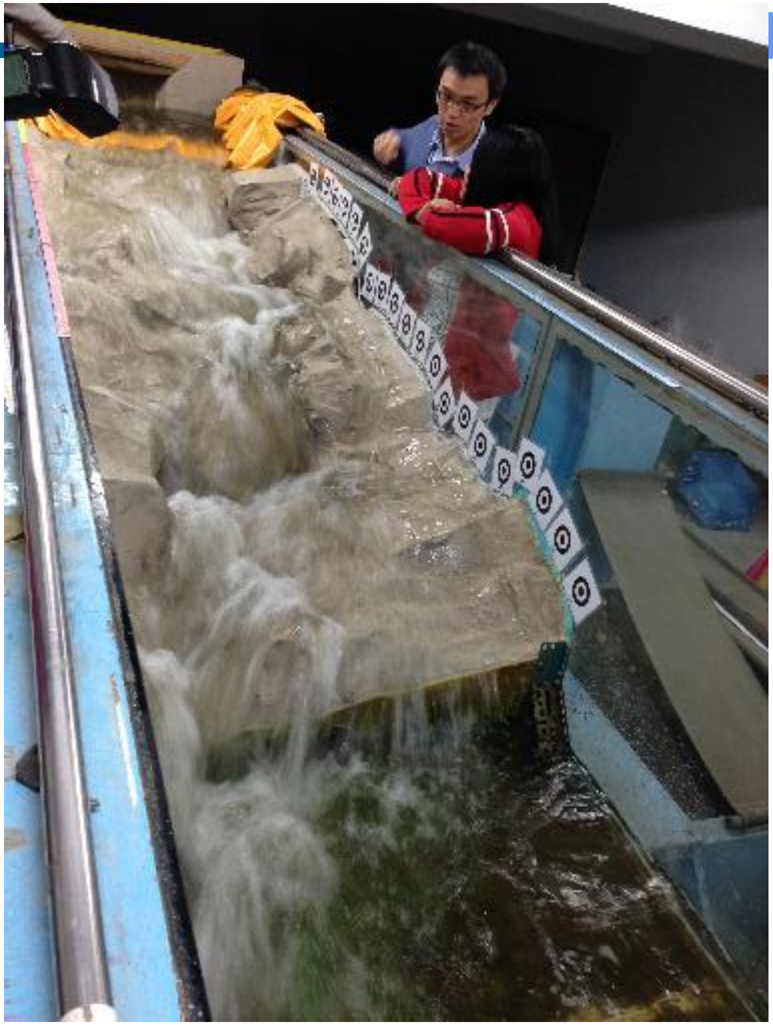
0.6 Flood Control



0.6 Flood Control

Flood on Sept., 2011

Flood way, Jeju, Korea

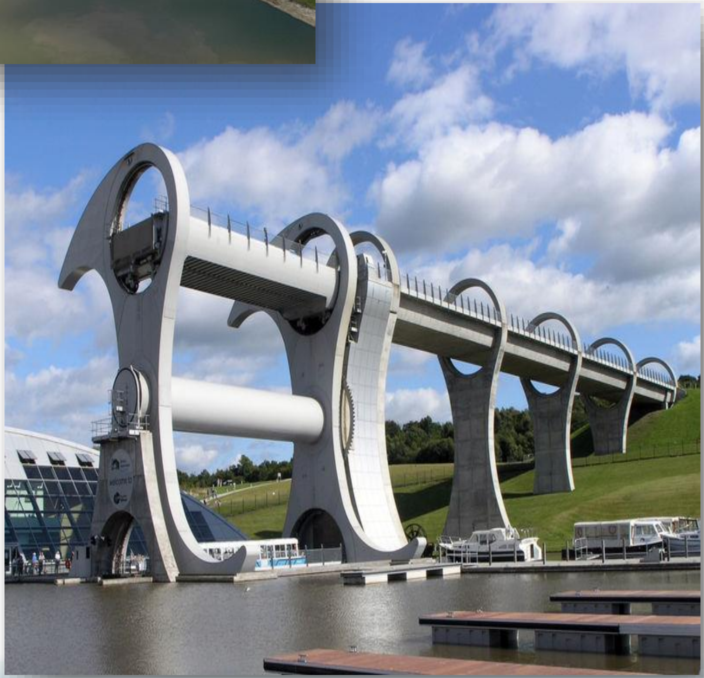


Flood test, NTU Channels

0.7 River Navigation

Mississippi River

Neckar River, Germany



Falkirk Wheel, UK

Ara Canal

Canal:

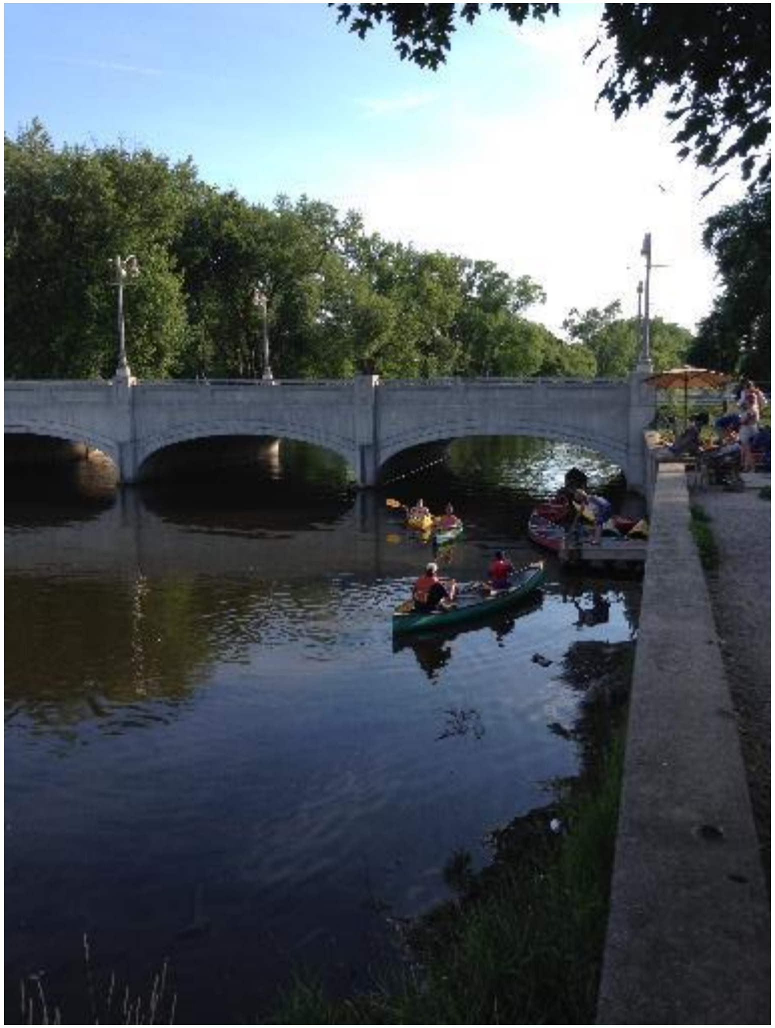
L: 18 km; W: 80 m; H: 6.3 m

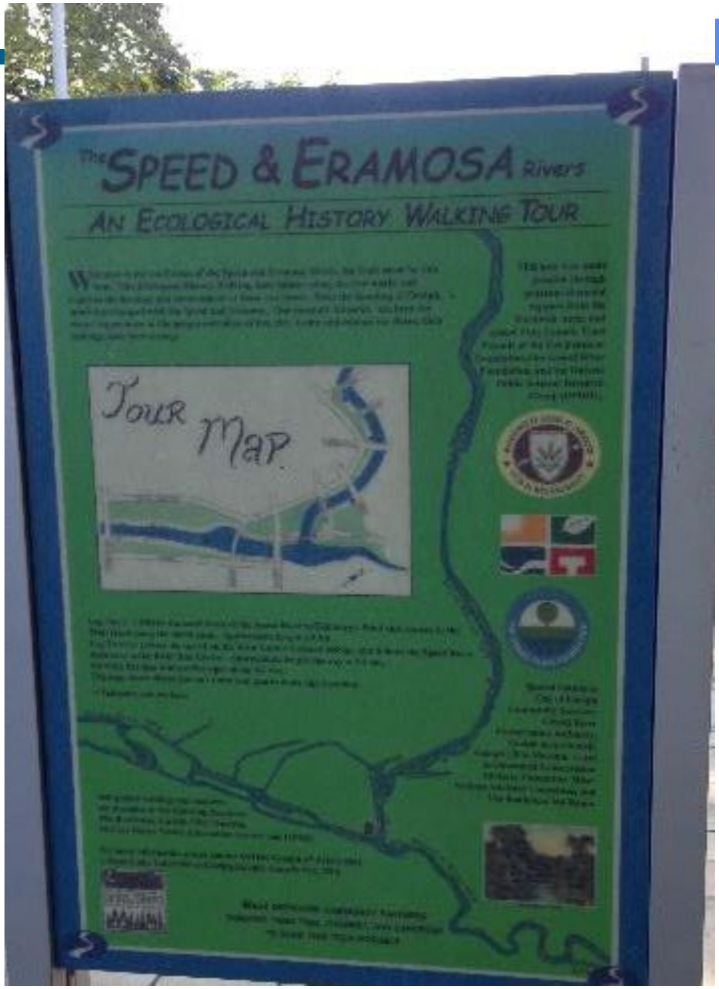
Photographed on July, 2016

0.8 River Recreation

Cherry Creek, Colorado

0.8 River Recreation





Grand River, Canada