Smart River Engineering

Chapter 3. Streamflow Measurement

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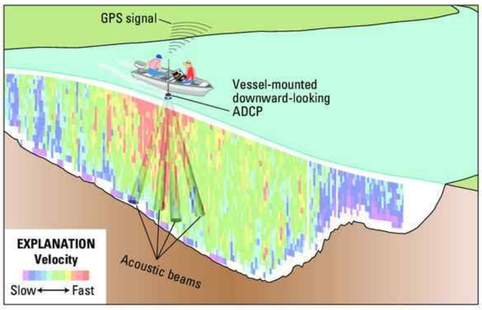
Streamflow Measurements

- As important as ever
  - Flash floods
  - Increased peak flows due to urbanization
  - Climate change
  - Proper design of flood protection structure becomes important

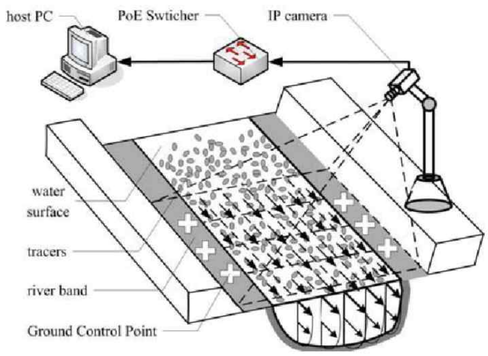
- IT-based techniques are being applied.
  - ADCP*
  - Lidar for bed topography
  - LS PIV*

- Innovation can hardly be noticed.

Discharge Measurement using ADCP



Surface Velocity Measurement using LSPIV



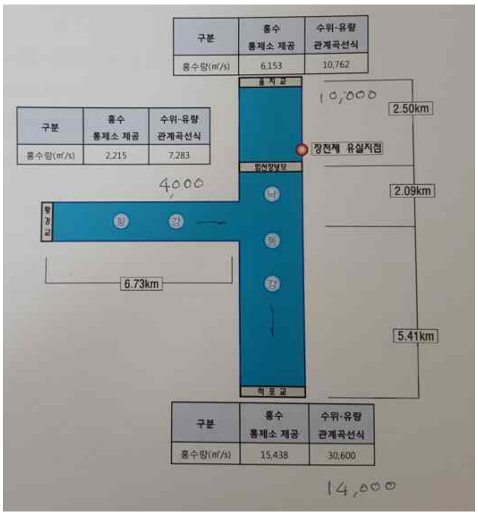
Stream Flows

- What do we measure?
  - volume or mass or their flowrates
  - stage or flow depth
  - bed materials

- Why do we measure?
  - for flood protection
  - for water supply
  - for environmental flow

  - To determine the design flood

Errors



- 2020년 낙동강 홍수량
  - 홍수통제소 제공 홍수량과 수위-유량 관계식에 의한 홍수량 차이 매우 큼
  - 홍수량이 크고 큰 하천일수록 오차 심함
  - 과학적이고 신뢰할 수 있는 공학적 방법 필요함

Flow Measurement Methods

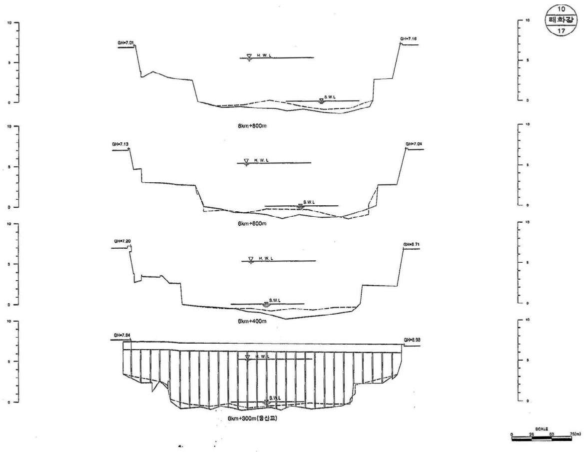
- Stage (water surface elevation)
  - visual observation
  - float
  - pressure sensor
  - electric resistance
- Discharge (non-structural)
  - current meter
  - diffusion
  - float
  - indirectly by Manning's equation
- Discharge (structural)
  - direct volume collection
  - weirs
  - flumes
  - orifice

Stage

- Stage is the water surface elevation measured from a horizontal datum, frequently mean sea level.

- Water depth is the water surface elevation measured from the thalweg of the cross section.
- So the reference level of the water depth changes from section to section.

Stage



• If we fix the reference height (datum), then the water surface elevations at each cross section can be compared. But if we use flow depth, we cannot.

2. Stage Measurement

Gauging Station (수위관측소)

섬진강 지류 율천 번암교 수위관측소 (장수군)

임진강 군남 수위관측소

• Normally the gaging station is attached to the bridge for better accessibility and management.

Stilling Well (관측정)

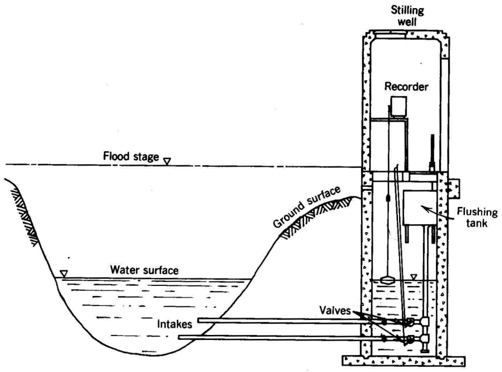


FIGURE 5.2 Typical stilling well installation for water stage recorder (from *Stevens Water Resource Data Book*, 4th Ed., Leapold and Stevens, January 1987).

- This type of installation removes short period water surface disturbances.

Guide Pulley (수위측정 장치)

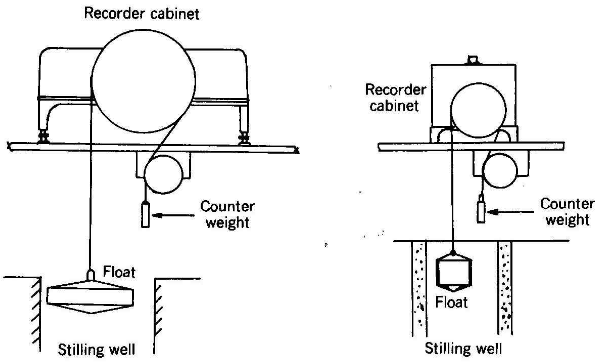


FIGURE 5.1 Typical guide pulley.

- The height of water surface is detected using the float in the stilling well.

Strip Chart Recorder (수위기록 장치)

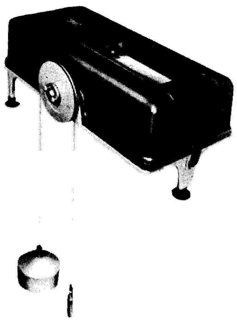


FIGURE 5.4 Stevens type A strip chart recorder (from Stevens, op. cit.).

Stage Measurement using Pressure Transducer (압력변환기에 의한 수위측정)

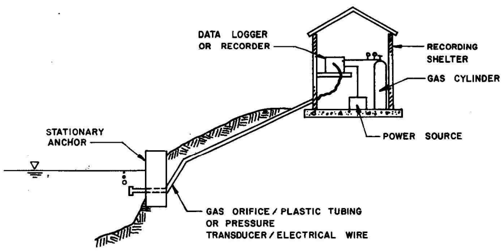


FIGURE 5.3 A gaging station with both a pressure transducer and nitrogen-gas-purge water-level sensing system.

- Difficult to install stilling well in mountainous region
- Recommended for short-term use
- Pressure is measured and transmitted through plastic pipeline
- The pressure data is converted to stage data

2009년 북측 황강댐 무단 방류 사건

- In Sep.6, 2009 N Korea discharged water through the gate of Hwang-gang Dam without notice
- At that time, the Imjin-gang River early warning system of K Water broke down.
- Six campers missing in rapids

- 이에 앞서 북측은 임진강 상류에 황강댐을 건설하였고 남측은 이에 대한 대응댐으로 군남조절지 건설 2003년 준공

Discharge Measurements

- Velocity-area method (유속면적법)
- Dilution (희석법)
- Float (부자법)
- Manning's equation
- Weirs and flumes
- Direct measure

Discharge Measurement in Streams

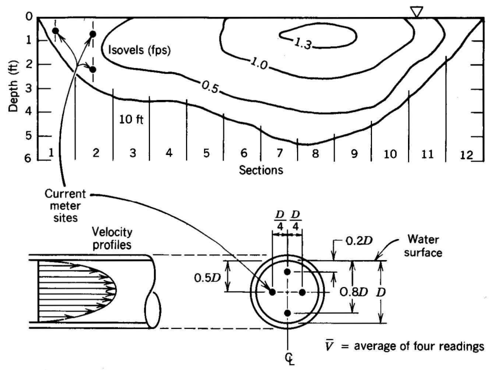
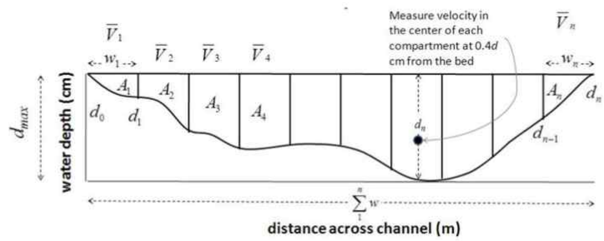


FIGURE 5.6 Velocity profiles with depth/area/velocity measurement points.

Velocity-Area Method

$$Q = \sum_i Q_i = \sum_i A_i \overline{V}_i$$



Q = Flow area * Flow velocity

Q = Depth * Width * Velocity (Units: m*m*(m/s) = m^3/s

Q = Σ (D_i x W_i x $\overline{V}_i$), over many subsections, i = 1 to n

For example: 0.2 m * 0.34 m * .09 m/s = .006 m^3/s

Current Meter

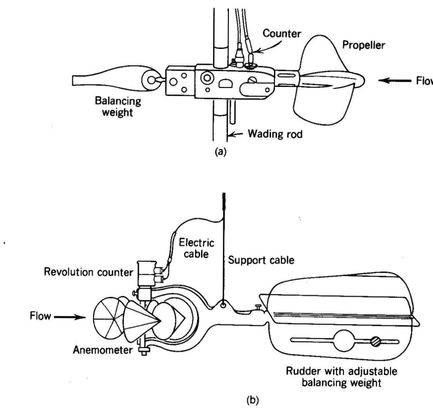


FIGURE 5.5 Current meters: (*a*) Propeller meter, and (*b*) price current meter.

0.03 < V < 10 m/s

Average Velocity

- Finite (or Reduced) Point Methods

Depth (m)	No. of Measures	Average Velocity
0.3 – 0.6	1	$\overline{V} = V_{0.6}$
0.6 – 3.0	2	$\overline{V} = 1/2(V_{0.2} + V_{0.8})$
3.0 – 6.0	3	$\overline{V} = 1/4(V_{0.2} + 2V_{0.6} + V_{0.8})$
> 6.0	5	$\overline{V} = 1/10(V_{s1} + 3V_{0.2} + 2V_{0.6} + 3V_{0.8} + V_{b1})$*

- $V_{0.2}$ means the velocity 0.2*d from the water surface.
- Vs1 and Vb1 mean the velocities measured from 0.3 m from the water surface and bed, respectively.

Flow Area Method 1

EXAMPLE PROBLEM 5.1

For a particular stream, estimate the flow rate (runoff for this case) using the following data for velocities measured at two depths (0.2 and 0.8 of the total) and the cross-sectional area corresponding to the velocity measures.

SECTION	SAMPLE DEPTHS	1	2	3	4	5
Velocity (m/s)	$0.2D$	0.4	0.8	1.2	1.0	0.6
	$0.8D$	0.3	0.6	1.3	1.2	0.6
Area (m^2)		3	6	10	8	4

Flow Area Method 2

Solution

$$Q = \sum_i Q_i = \sum_i A_i \bar{V}_i = \sum_i A_i (V_{0.2} + V_{0.8})_i / 2$$

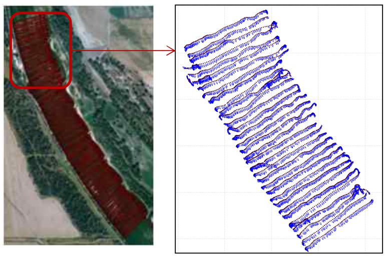
$$= 3(0.35) + 6(0.70) + 10(1.25) + 8(1.1) + 4(0.6)$$

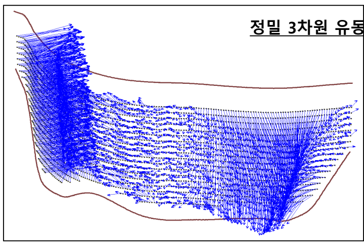
$$= 1.05 + 4.20 + 12.50 + 8.8 + 2.4 = 29.00 \text{ m}^3/\text{s}$$

Acoustic Doppler Current Profiler (1)

초음파 도플러 효과 이용 유속 측정

대규모 하천 유역 2차원 유동장





정밀 3차원 유동장

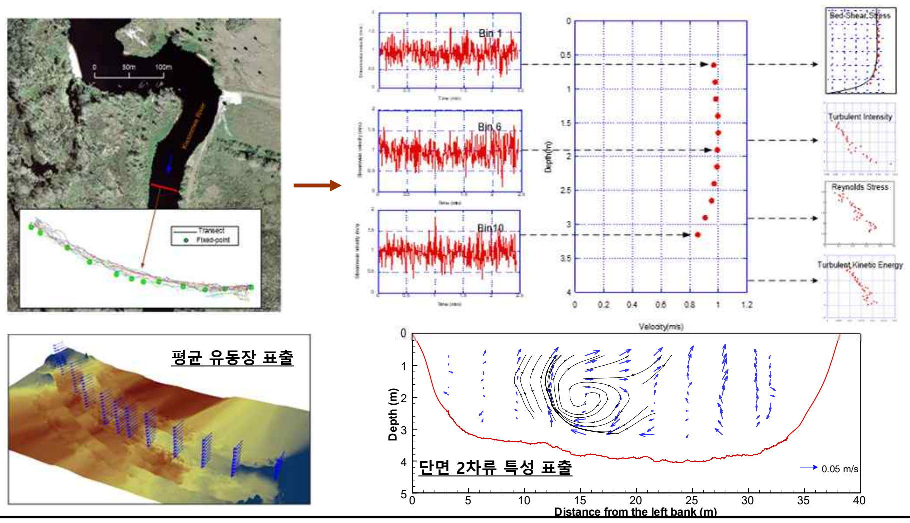
ADCP (2)

measurement at bridge
(stationary measurement)

measurement using boat
(moving-vessel measurement)

ADCP (3)

- ADCP 활용 평균 유동장 및 난류 표출 개념도



Discharge Measurement using Dilution

희석을 이용한 유량측정

- Mass in: $c_i \times vol$
- Mass out: $Q \times \sum_{0}^{t_f} c_j \Delta t_j$
- Mass in = Mass out: $Q = \dfrac{c_i \times vol}{\sum_{0}^{t_f} c_j \Delta t_j}$

we assume Q = const.

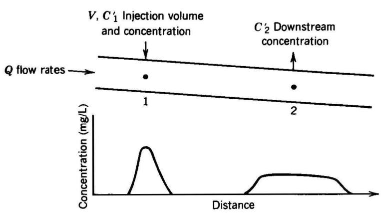


FIGURE 5.7 Chemical mass balance.

Dilution

EXAMPLE PROBLEM 5.2

At 07:00 hr, 400 kg of a tracer was injected immediately into a river. Two sampling points were used downstream at 14 km and 25 km. Tracer concentrations obtained from a sampling program are shown below. What is the flow rate downstream using the measurements at 14 km?

TIME	CONCENTRATION (mg/L)	
(hr)	14 km	25 km
0700	0	0
0800	0	0
0900	3	0
1000	10	0
1100	20	2
1200	15	9
1300	14	18
1400	7	15
1500	2	11
1600	2	7
1700	1	4
1800	1	3
1900		2
2000		1
2100		1

Dilution

7	0	0		
8	0	0	0	0
9	3	0	5400	0
10	10	0	23400	0
11	20	2	54000	3600
12	15	9	63000	19800
13	14	18	52200	48600
14	7	15	37800	59400
15	2	11	16200	46800
16	2	7	7200	32400
17	1	4	5400	19800
18	1	3	3600	12600
19	0	2	1800	9000
20		1	0	5400
21		1	0	3600
22		0	0	1800
			270000	262800

Dilution

Solution

Using the mass balance approach and Equation 5.4, at the 14 km mark, the cumulative concentration is 75 mg-hr/L and

$$Q = (400\ \text{kg} \times 10^6\ \text{mg/kg})/(75\ \text{mg-hr/L} \times 3600\ \text{sec/hr}) = 1480\ \text{L/s}$$

Note that the mass has decreased to 73 mg-hr/L at the 25-km marker. The flow rate estimate at 25 km would thus be greater than that at 14 km. The greater the loss of concentration, the greater the flow rate estimate. □

@ 14 km, Q = 1.48 cms

@ 25 km, Q = 1.52 cms

Discharge Measurement using Manning's Equation

- 1998년 곡릉천 좌안 상수도 취수시설 주변 제방 붕괴 사건

Discharge Measurement using Manning's Equation

- 1998년 곡릉천 좌안 상수도 취수시설 주변 제방 붕괴 사건

Discharge Measurement by Weir

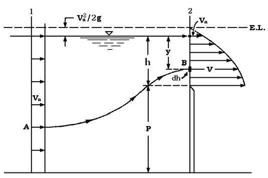


Fig. 11.35 Weir flow (simplified)

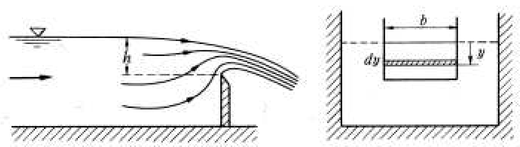


그림 7-18 직사각형 위어

$$Q = C\frac{2}{3}b\sqrt{2g}h^{3/2}$$

LSPIV 1

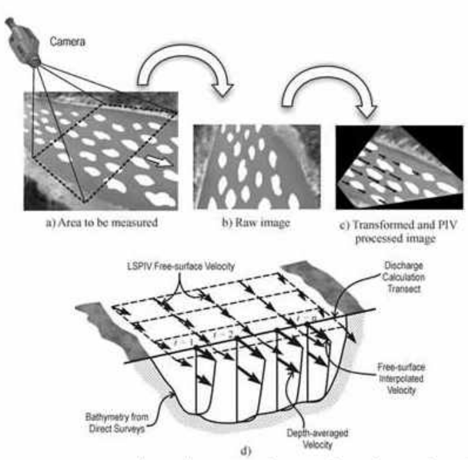


Figure 3 — Large-scale particle image velocimetry (LSPIV) principle and operational components: (a) illumination and seeding; (b) image recording; (c) image reconstruction to obtain ortho-rectified images and image processing; (d) algorithm for estimation of stream discharge using the free surface LSPIV measurements

LSPIV 2

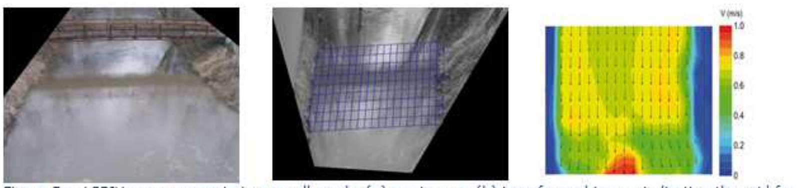


Figure 5 — LSPIV measurements in a small creek: (a) raw image; (b) transformed image indicating the grid for velocity vector computation; (c) resultant mean vector field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Bulletin

Weather • Climate • Water

July 2008

Developments in hydrometric technology: new and emerging instruments for mapping river hydrodynamics

by Marian Muste[1], Won Kim[2] and Janice M. Fulford[3]

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The article [pdf]

- Don’t be afraid to dream big, but remember dreams without goals are just dreams and they ultimately fuel disappointment. So have dreams but have goals. To achieve these goals, you must apply (discipline) and (   ) everyday. You have to work at it. I try to give myself a goal everyday. Sometimes it’s just not to curse somebody out.

Denzel Washington