Kingdom of Cambodia

Nation Religion King

❉❉❉❉❉

Ministry of Water Resource
And Meteorology

Japan International
Cooperation Agency

River Basin Water Resources Utilization Project (RBWRU)

MANUAL ON DISCHARGE MEASUREMENT BY CURRENT METER AND FLOATS

SEPTEMBER 2015

Prepared by

KODAMA Masayuki

(Short-term Expert)

THE RIVER BASIN WATER RESOURCES UTILIZATION PROJECT
（Support to Improvement and Reinforcement in Meteorological and Hydrological Observation Network）

MANUAL ON DISCHARGE MEASUREMENT BY CURRENT METER AND FLOATS

Table of Contents

Page

CHAPTER I. INTRODUCTION 1
1.1 Authority, Objective and Notification 1
1.2 Purpose of Discharge Measurements 1
1.3 Methods of Discharge Measurements 1
1.4 Target Hydrological Stations 4
1.4.1 Target River Basins 4
1.4.2 Target Hydrological Stations 4
1.4.3 Facilities of the Station 4
CHAPTER II. DISCHARGE MEASUREMENT BY CURRENT METER
2.1 General 6
2.1.1 Objective of the Discharge Measurements 6
2.1.2 Method of Discharge Measurements by Current Meter 6
2.2 Instruments and Equipment 7
2.2.1 Electromagnetic Current Meter 7
2.2.2 Width Measuring Equipment/tools 7
2.2.3 Depth Measurement Equipment/tools 9
2.2.4 Inflatable Boat and Outboard Engine 10
2.2.5 Safety Instruments 10

2.3 Procedure for Current Meter Measurement of Discharge 11
2.3.1 Selection of Site for Measurements 11
2.3.2 Layout and Stationing of Partial Sections and Velocities 12
2.3.3 Depth Measurements 14
2.3.4 Velocity Measurements 14
2.3.5 Recording Field Notes 15
2.3.6 Current Meter Measurements by Wading 17
2.3.7 Current Meter Measurements from Bridge 18
2.3.8 Current Meter Measurements from Boat 19
2.4 Measurement of Water Depth 21
2.4.1 By Leveling Staff Gauge 21
2.4.2 By Wading Roads 21
2.4.3 By Sounding Reel and Cable 22
2.4.4 By Measuring Tape 24
2.5 Measurement of Velocity 27
2.5.1 General 27
2.5.2 One-point Method 27
2.5.3 Two-point Method 27
2.5.4 Two-tenth Method 28
2.5.5 Three-point Method 29
2.5.6 Five-point method 29
2.5.7 Subsurface Method 29
2.5.8 Selection of Method 29
2.6 Calculation of Flow 30
2.7 Evaluation of the Result 34
2.8 Formation of a Team for Discharge Measurement 34
CHAPTER III. DISCHARGE MEASUREMENT BY FLOATS
3.1 Measurement Methods 36
3.2 Required Equipment and Tools 36
3.3 Formation of a Team 37
3.4 Procedure of Measurement by Floats 37
3.4.1 General 37

3.4.2 Selection of Site 37
3.4.3 Setting up Velocity Lines 38
3.4.4 Check of Flow Condition 39
3.4.5 Flow Velocity Calculation 39
3.4.6 Cross Section Survey 39
3.4.7 Recording 40

CHAPTER IV. MAKING RATING CURVES

4.1 General 41
4.2 Graphic Plotting of Water Level-Discharge 41
4.2.1 General 41
4.2.2 List of Discharge Measurements 42
4.2.3 Arithmetic Plotting Scales 42
4.2.4 Computer Plotting of Discharge Measurements 43
4.2.5 Making Approximate Curve 44

CHAPTER V. CALCULATION OF DISCHARGE BY H-Q CURVES

5.1 General 46
5.2 Calculation of Daily Mean Discharge by H-Q Curves 46
5.3 Calculation of Monthly and Annual Values 48
5.3.1 General 48
5.3.2 Monthly and Annual Values 48

Tables

Table 1-1 Kind of Methods for Discharge Measurement 2
Table 1-2 Target Hydrological Stations of RBWRU in 2015 5
Table 2-1 Recommended Interval of Velocity Line 13
Table 2-2 Air correction table, giving differences, in meters, between vertical length and slant length of sounding line above water surface for selected vertical angles 25
Table 2-3 Wet-line table, giving difference, in meters, between wet-line length and vertical depth for selected vertical angles 26
Table 2-4 Coefficients to Obtain Mean Velocity from Various Depth of Observation 28
Table 2-5 Selection of Methods for Obtaining Mean Velocity at a Vertical Line 30
Table 2-6 Charts for Determining Depth of Current Meter at 0.2D, 0.6D and 0.8D 31

Table 2-7 Recording and Calculating Form for Discharge Measurement ··· 32
Table 2-8 Discharge Measurement Note ··· 33
Table 2-9 Member of Team for Discharge Measurement by Current Meter ··· 34
Table 3-1 Member of Team for Discharge Measurement by Float ··· 37
Table 3-2 Number of Velocity Lines by Float Measurement ··· 38
Table 3-3 Discharge Calculation by Floats ··· 37
Table 5-1 Kind of Water Level Records ··· 46
Table 5-2 Calculation of Discharge by H-Q Curves ··· 47
Table 5-3 Important Daily Values ··· 47
Table 5-4 Calculation of Monthly and Annual Values ··· 49

Figures

Figure 2-1 Typical Cross Section of Alternate Water Depth Line and Velocity Line ··· 6
Figure 2-2 Typical Cross Sections of Two-Trapezoidal Method ··· 13
Figure 2-3 Angle Alpha in the Oblique Flow ··· 15
Figure 2-4 Determination of the position in a cross section using the stadia method ··· 21
Figure 2-5 Determination of the position in a cross section using the angular method ··· 21
Figure 2.6 Measurement of Water Depth by Sounding Weight and Cable ··· 23
Figure 2-7 Typical Sounding Line by Downstream Drift ··· 23
Figure 2-8 Typical Vertical-velocity Curve ··· 27
Figure 4-1 Arithmetic Plotting of Water Level Discharge Relation ··· 42
Figure 4-2 Arithmetic Plotting of Water Level-Discharge Relation Shows a Shift in Lower Part ··· 43
Figure 4-3 Single H-Q Curve ··· 45
Figure 4-4 Two H-Q Curves for Low and High Water Levels ··· 45

PHOTO/ILLUST.

Photo/illust.-1 Electromagnetic Current Meter (AEM1-D) ··· 7
Photo/illsut.-2 Measuring tape and synthetic fiber rope ··· 8
Photo/illust.-3 GeoMax Zipp10 ··· 8
Photo/illust.-4 GPS instruments ··· 8
Photo/illust.-5 Rods (50 cm each) ··· 9

Photo/illust.-6 Leveling Staff (5 m long) ········· 9
Photo/illust.-7 Sounding reel ········· 9
Photo/illust.-8 Inflatable Rubber Boat ········· 10
Photo/illust.-9 Outboard Engine ········· 10
Photo/illust.-10 Boards ········· 10
Photo/illust.-11 Life vest ········· 10
Photo/illust.-12 Stretching a rope ········· 12
Photo/illust.-13 Depth Measurement from boat ········· 14
Photo/illust.-14 Velocity Measurement ········· 14
Photo/illust.-15 Display unit of AEM1-D ········· 16
Photo/illust-16 Wading Measurement using rods ········· 17
Photo/illust-17 Measurement from boat ········· 20
Photo/illust.-18 Attentions Required for Measurement of Water Depth ········· 24
Photo/illust.-19 Evaluation of the Result ········· 32
Photo/illust.-20 Measurement by Floats ········· 36
Photo/illust.-21 Stretch not to be Adopted ········· 38
Photo/illust.-22 Poles at Measuring Site ········· 38
Photo/illust.-23 Setting up Velocity Lines ········· 38
Photo/illust.-24 Vertical Vibration and Deviation of Flow Course ········· 39

FORMS

FORM-33 Two-tenth (0.2D) Method ($0.6\ m<D\leqq 3\ m$, $v_m=0.87v_{0.2D}$)

FORM-34 2-point Method ($0.6\ m<D\leqq 3\ m$, $v_m=(v_{0.2D}+v_{0.8D})/2$) and/or 3-point Method ($3.0\ m<D\leqq 6.0\ m$, $v_m=(v_{0.2D}+2\times v_{0.6D}+v_{0.8D})/4$)

FORM-35 5-point Method ($6.0\ m<D$) including 1-point ($v_m=v_{0.6D}$), 2-point ($v_m=(v_{0.2D}+v_{0.8D})/2$ and 3-point ($v_m=(v_{0.2D}+2\times v_{0.6D}+v_{0.8D})/4$) methods

FORM-36 For Float Method in Flood Time

FORM-37 Discharge Measurement Note

FORM-41 Calculation of Discharge by Applying H-Q Curves

FORM-42 Daily mean, Monthly Mean and Annual Mean Discharges

References

Ref. 1 Technical Criteria for River Works: Practical Guide for Survey, Ministry of Land, Infrastructure, Transport and Tourism

Ref. 2 Hydrological Observation Illustration – Japanese version", Chubu Construction Incorporated Association

Ref. 3 Manual on Stream Gauging Volume I-Field Work, World Meteorological Organization WMO-No.1044

Ref. 4 Manual on Stream Gauging Volume II-Computation of Discharge, World Meteorological Organization WMO-No.1044

Ref. 5 Guide to Hydrological Practices Volume I Hydrology-From Measurement to Hydrological Information, World Meteorological Organization WMO-No.168

Ref. 6 Guide to Hydrological Practices Volume II Management of Water Resources and Application of Hydrological Practices, World Meteorological Organization WMO-No.168

Ref. 7 Water Measurement Manual, U.S. Department of the Interior, Bureau of Reclamation, Third Edition

CHAPTER I GENERAL

1.1 Authority, Objective and Notification

This manual has been prepared by Kodama Masayuki, a short-term expert to the River Basin Water Resources Utilization Project under Japan International Cooperation Agency in the Ministry of Water Resources and Meteorology in Cambodia. The manual has prepared aiming to reinforce the capacity of Cambodian counterparts personnel in carrying out discharge measurement in the rivers and canals so that discharge data at the target observation stations can be properly collected, and management system for meteorological and hydrological data is built.

This manual has been made based on and revised largely from the manual for "River Discharge Measurement Manual (Draft) May 2007" for The Basin-wide Basic Irrigation and Drainage Master Plan Study, JICA Study Team, referring to the publications and documents listed in the last part of table of contents in this manual.

This manual, however, should be modified through the practical use by counterparts.

1.2 Purpose of Discharge Measurements

The discharge (stream flow) is defined as an amount of water in a river or an open channel including any sediment or other solids that may be dissolved or mixed with it.

Discharge cannot be measured directly, but must be computed from variables that can be measured directly, such as water depth and flow velocity. A relationship of water level and discharge can be made based on the discharge measurement (H-Q curve). Discharge measurement is to be executed mainly to obtain data for development of H-Q curve. Discharge in a river or open canal is calculated by applying a water level (water depth) to H-Q curve(s) or discharge rating curve in another word which have to be developed beforehand.

Records of water level are required for calculation of discharge for long period. The survey work of water level in the river or open channel is discussed in another manual i.e. Manual on Rainfall and Water Level Observation.

1.3 Methods of Discharge Measurements

The discharge measurement is generally classified into several methods as summarized in Table 1-1 in accordance with the way of determining average flow velocity.

Table 1-1 Kind of Methods for Discharge Measurement

Classification	Name	Subjects to be measured directly	Explanation	Main equipment/tool
Velocity-area method:	Float method	The discharge is obtained by average flow velocity and cross section area	This should be used where flood measurements are needed and the measuring structure has been destroyed, or it is impossible to use a meter, where there is the presence of a large amount of material in suspension, or when a discharge measurement must be made in a very short time.	Wooden disks, bottles partly filled, styrene foam, floating debris, rod floats which are usually made of wood, weighted on one end so they will float upright in the stream, etc.
	Current meter method	Water depth, surface water width, velocity in each segment	This uses some type of current meter to measure stream velocity. It is made by sub-dividing a stream cross section into segments and measuring the depth and velocity in a vertical within each segment. The summation of these segment discharges is the total discharge.	• Mechanical meter －Vertical axis (Price, etc.), －Horizontal axis (Otto, Hoff, Valeport, etc.) • Electromagnetic meter • Acoustic Doppler Velocimeter (ADV) • Optical current meter
	Acoustic (ultra-sonic) and electromagnetic methods		New deployment methods such as unmanned tethered boats allow us to make ADCP measurements from a bridge or cableway making ADCP measurements practical at sites where it is difficult to launch a manned boat. The ADCP method uses a moving boat to traverse the stream. The ADCP method measures velocity magnitude and direction using the Doppler shift of acoustic energy reflected by material suspended in the water column providing essentially a complete vertical velocity profile. It also tracks the bottom providing stream depth and boat positioning.	• Acoustic Doppler Velocimeter (ADV) • Acoustic Doppler Current Profilers (ADCP)
	Tracer dilution method		This method used originally salts as the tracer injected in the stream. Radioactive tracers have been used successfully, but handling problems have limited widespread use. The development of stable fluorescent dyes and fluorometers that can measure them at very low concentrations has greatly enhanced the use of dilution methods.	Salts, Fluorescent dyes. Fluorometers

Hydraulic structure method:	Discharge formula method	The discharge can be obtained by applying overflow depth on the weir to pre-developed formula.	This method measures discharge by observing the head on measuring structures, or manmade controls. The discharge can be obtained by applying the water depth to the discharge formula which is developed beforehand by experiment.	• Thin-plate weirs – Triangular-notch weirs – Rectangular weirs, etc. • Broad crested weirs – Round-nosed horizontal-crested weirs, etc. • Standing-wave flumes – Parshall flumes, etc.
By indirect methods	Slope-area method, Flow over dams and weirs, & other names	Water depth, roughness coefficient, cross sectional area, etc.	In the slope-area method, discharge is computed on the basis of a uniform flow. The Manning equation is commonly applied. The Manning equation is also valid for the non-uniform flow. In the flow over dams and weirs method, the equation of overflow spillway is applied.	In case flow over dams and weirs method is applied the overflow weir/crest are required.

1.4 Target Hydrological Stations

1.4.1 Target River Basins

The project of River Basin Water Resources Utilization (RBWRU) aims to improve and reinforce in meteorological and hydrological observation network in the following six river basins, i.e. Sangkae, Moung Russei, Pursat, Boribo, Prek Thnot and Slakou River Basins. These rivers are located in Battambang, Pursat, Kompong Chhnang, Kompong Speu, Kandal and Takeo provinces.

Hydrological stations have been constructed in three river basins i.e. Sangkae, Moung Russei and Pursat river basins have in 2015.

1.4.2 Target Hydrological Stations

Fifteen hydrological stations have been constructed by RBWRU in 2015 in the Sangkae, Moung Russei and Pursat river basins. Of them, six stations have automatic water level gauges in which data of water level as well as rainfall are recorded in the data logger. Nine stations have staff gauges which an observer has to observe by eyes and record on the data sheet by hand. Table 1-2 summarized main information of hydrological stations constructed by RBWRU in 2015.

Further, some 18 hydrological stations will be constructed by RBWRU in 2016 and 2017.

1.4.3 Facilities of the Station

There are two type of hydrological station of RBWRU. One type has staff gauges only which are installed at river/channel side. The water level is observed and recorded on the data sheet by an observer two times in a day i.e. at 7 am and 7 pm. This type of station is expressed as "MANUAL" in Table 1-2.

The other type has a water level sensor and data logger powered by a solar panel. These instruments are installed at foot of river side. A recorder's house in which the data logger is stored was constructed at river side. Water level is recorded every 15 minutes and sent to computers in the office of RBWRU and office of PDWRAM by GPRS (General Paket Radio Service) modem. This type of station is expressed as "AUTO" in Table 1-2. The water level at AUTO station is also observed and recorded in the same way as that at MANUAL station.

The survey work of water level in the river or open channel is discussed in another manual i.e. "Manual of Rainfall and Water Level Observations".

Table 1-2 Target Hydrological Stations of RBWRU in 2015

Table 1-2 Target Hydrological Stations of RBWRU in 2015

No.	Name of station		East	North	River/ stream	Province	District	Commune	Village	Name of observer	Telp. No.	Type of station	Brand name of gauges	SIM card
1	Andaek Herb		279091	1420160	Sangkae	BTB	Ratanak Mondul	Ornderk Heb	Thvak	Hang Heng	088 9666767 092 442720	AUTO	WL450, RG600	Smart 070 438410
2	Bassac Dam	Reservoir	318121	1389897	Moung Russei	BTB	Rokha Kiri	Bassac	Bassac	You Ras	092 548911	AUTO	WL450, RG600	Cellcard 078 778710
3		Spillway	318151	1389977								AUTO	WL450	
4	Prek Chik Left Canal		324982	1398220	Moung Russei	BTB	Rokha Kiri	Prek Chik	Prek Chik			MANUAL	STG	–
5	Prek Chik Right Canal		325448	1398381	Moung Russei	BTB	Rokha Kiri	Prek Chik	Prek Chik			MANUAL	STG	–
6	Prek Am		329953	1410653	Moung Russei	BTB	Moung Russei	Robos Mongkol	Kon Ka enk pi	You Sokhoeun	017 478997	AUTO	WL450, RG600	Cellcard 078 855312
7	Prek Am Canal		329882	1410972	Moung Russei	BTB	Moung Russei	Robos Mongkol	Kon Ka enk pi	You Sokhoeun	017 478997	MANUAL	STG	–
8	Tades		354882	1360537	Pursat	Pursat	Phnum Kravanh	Som Raong	Tades			AUTO	WL450, RG600	Smart 096 2004331
9	Bak Trakoun		364762	1366129	Pursat	Pursat	Phnum Kravanh	Prongil	Ou Bak Tra	Choeung Chan	097 2483032	AUTO	WL450, RG600	Cellcard 078 855319
10	Khum Veal		384090	1388529	Pursat	Pursat	Kandieng	Veal	Kracher badach	Sok Makara	092 927727	MANUAL	STG	–
11	Charek Left Canal		390148	1394343	Pursat	Pursat	Kandieng	Sya	Kompong Sambour	Sam Yoeun	097 5082229	MANUAL	STG	–
12	Ptes Kor Canal		389851	1392666	Pursat	Pursat	Kandieng	Onlong Verl	Beng Chhouk			MANUAL	STG	–
13	Peam		360645	1357558	Steung Arai	Pursat	Phnom Krovanh	Somraong	Peam Hav	Kry Marady	096 6556647	MANUAL	STG	–
14	Santre		372418	1355284	Prey Khlong	Pursat	Phnom Kravanh	Santre	Kaset borey			MANUAL	STG	–
15	Svay Daun Keo	In the Damnak Ampil canal	351574	1389524	Svay Don Keo	Pursat	Bakan	Ta Lou	Thmey			MANUAL	STG	–
		Inlet at gate, Damnak Ampil side	351574	1389524								MANUAL	STG	–
		Gate, Damnak Ampil side	351574	1389524								MANUAL	STG	–
		Overflow crest of spillway	351596	1389514								MANUAL	STG	–
		Inlet at gate, Prek Chik side	351596	1389514								MANUAL	STG	–
		Gate, Prek Chik side	351508	1389550								MANUAL	STG	–

Note: ARG: Automatic Rain Gauge

AUTO; Automatic water level sensor and rain gauge with data logger

AWL: Automatic Water Level Gauge

LOGGER & TEME; Data logger iLOGS46, Masermic, and sent by GPRS (General Packet Radio Service)

MANUAL; Reading and writing by human

RG600; Rain gauge, Global Water

SMS; Short message serivices

STG; Staff gauges

WL450; Watre level sensor, Global Water

CHAPTER II

DISCHARGE MEASUREMENT BY CURRENT METER

2.1 General

2.1.1 Objective of the Discharge Measurements

Discharge measurements are made at each gaging station to determine the discharge rating (H-Q curve) at the site. Initially the discharge measurements are made at various water levels at the station to define the H-Q curve. Measurements are then made at periodic intervals, usually monthly, and also during extreme events such as floods or droughts to verify the rating, extend the rating, or to define any changes in the rating caused by changes in stream-channel conditions.

Discharge measurements are made by the several methods discussed in the Chapter I. However, the basic instrument most commonly used in making the measurement is a current meter. The observations of water velocity and depth are usually made in the cross section of a stream. This is referred to as the conventional method of making a discharge measurement.

2.1.2 Method of Discharge Measurements by Current Meter

A current meter measurement is made by sub-dividing a stream cross section into segments and measuring the depth and velocity in a vertical within each segment. The total discharge for a current meter measurement is the summation of the products of the partial areas of the stream cross section and their respective average velocities. This computation is expressed by the equation:

$$Q = \sum_{i=1}^{n} q_i = a_i\, v_i \qquad (2.1)$$

where Q= total discharge in cubic meters per second (m3/sec), a_i= cross-section area in square meters (m^2) for the i^{th} segment of the n segments into which the cross section is divided, and v_i= the corresponding mean velocity in meters per second (m/sec) of the flow normal to the i^{th} segment, or vertical.

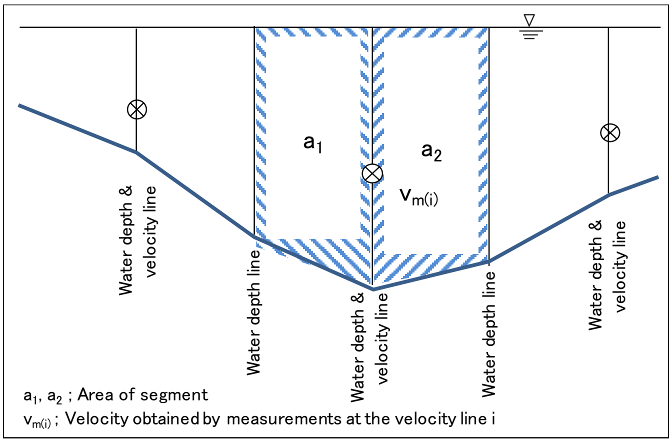


Figure 2-1 Typcial Cross Section of Alternate Water Depth Line and Velocity Line

A method shown in Figure 2-1 is the one which has been ruled by Ministry of Land Infrastructure, Transport and Tourism in Japan several decades ago. In this method, stream cross section is sub-divided into segments by two vertical lines (water depth line and velocity line) which are arranged alternately with a constant distance. One water depth line is arranged at each of the right side and left side of the velocity line. Accordingly two trapezoidal segments are formed by one velocity line and two water depth lines. In this rule the water depth is required to be measured at all depth lines and velocity lines.

The discharge can be calculated by the following equation.

$$q_1 = v_m \times (a_1 + a_2) \qquad (2\text{-}2)$$

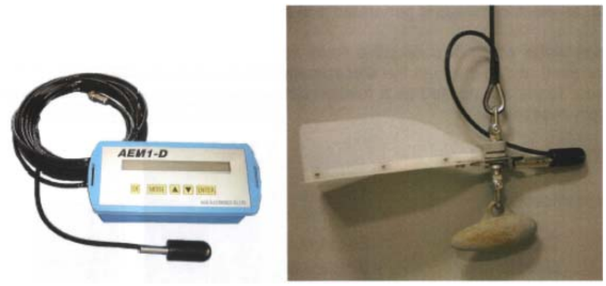
Where, v_m is a mean velocity at the velocity line, a_1 and a_2 are cross sectional area between two vertical lines, q_1 is discharge of two segments formed by one velocity line.

The interval of velocity lines and water depth lines are to be determined by the width of water surface which varies from time to time. This issue is discussed in the following section 2.3.2 (2).

2.2 Instruments and Equipment

2.2.1 Electromagnetic Current Meter

An electromagnetic current meter is based on the principle that a conductor (water) moving through a magnetic field will produce an electrical current directly proportional to the speed of movement (Faraday’s law). RBWRU will use an electromagnetic current meter (AEM1-D) as shown in Photo/illust.-1.



Photo/illust.-1 Electromagnetic Current Meter (AEM1-D): Left: Sensor with cable, display Right; Assembled with weight and vane

Advantages of the electromagnetic current meter are as follows:

a) No moving parts;

b) Direct read-out of velocity;

c) In oblique flow the velocity measured is normal to the measuring section when the meter is held normal to the measuring section;

d) Will measure lower velocities than rotating element current meters, even though uncertainties will be relatively high.

AEM1-D ensures to measure the velocity at the 3 cm depth.

A significant limitation of electromagnetic meters is that they are susceptible to electrical interference and require zero stability tests.

The manufacture recommends the equipment should be checked by him in every one or two years.

2.2.2 Width Measuring Equipment/tools

(1) Measuring tape and synthetic fiber rope

The horizontal distance to any vertical in a cross section is measured from an initial point on the bank. If a bridge is used regularly for making discharge measurements it should be marked at 1 m intervals by paint marks. Distance between markings is estimated or measured with a rule or pocket tape. For measurements made by wading, from boats or from unmarked bridges, a measuring tape (Photo/illust.-2) is used. For wide streams of more than 50 m a synthetic fiber rope can be used together with the measuring tape to assist marking during measurement.

Photo/illsut.-2 Measuring tape and synthetic fiber rope

For very wide streams of several hundred meters or more, where conventional measuring methods cannot be used, surveying methods or Global Positioning Systems (GPS) may be used as described hereunder.

(2) Surveying methods of width measurement by theodolite/electronic total station

For very wide streams where it is not practical to string a tape or rope width measurements from a boat, surveying methods should adopted to measure stream width and stationing for measurement points. An electronic total station, GeoMax Zipp10 (Photo/illust.-3) should be used for surveying methods. Accurate distance measurement with total station can be made over distance of more than 1.5 km, provided that the target/reflector can be seen and is not obstructed by intervening objects.

Photo/illust.-3 GeoMax Zipp10

Global Positioning System (GPS) instruments, Leica Viva GS15 (Photo/illust.-4) should be used for measurement of very wide streams such as flood plains that may be more than several kilometers. GPS instruments utilize satellite telemetry from a network of 24 satellites and radio trilateration to compute positions for any point on the earth. To obtain the accuracy necessary for a discharge measurement the raw GPS positions must have differential corrections applied on the basis of simultaneous readings at a base station.

Photo/illust.-4 GPS instruments

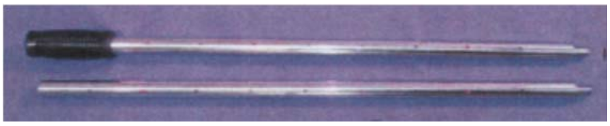
(3) Convex rule

A convex rule of 2 m, 3 m or 5 m will be a very useful tool to measure a short distance e.g. a distance between two markers on the rope, length from center of the current meter to the bottom of sounding weight.

2.2.3 Depth Measurement Equipment/tools

(1) Rods

Two stainless steel round rods, is shown in the Photo/illust.-5. Two rods can be assembled by screw. The sensor of meter is mounted on the sliding support and is set at the desired position on the rod by sliding the support. The round rod has the advantage that it can be assembled into various lengths using the 0.3 m sections and is easy to store and transport when disassembled.



Photo/illust.-5 Rods (50 cm each)

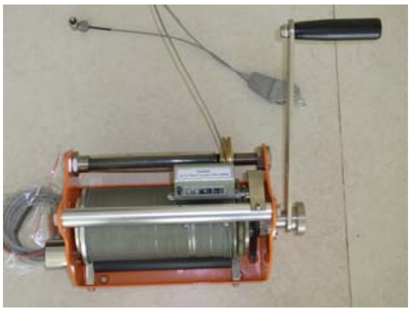
(2) Leveling Staff

A leveling staff (Photo/illust.-6) can be used for measuring water depth by wading or from boat. The use of leveling staff has the advantage of that the depth measurement can be done quickly since it does not need unwinding and winding wire or cable.

Photo/illust.-6 Leveling Staff (5 m long)

(3) Sounding reel (Gauging winch)

A sounding reel WS250 is shown in the photograph Ltd. (Photo/illust.-7). The length of wire cable and handling weight is 50 m and 50 kg respectively. The sounding reel has a drum for winding the sounding cable, a crank and ratchet assembly for raising and lowering the weight or holding it in any desired position and a depth indicator.



Photo/illust.-7 Sounding reel

(4) Measuring tape

A measuring tape made of fiber glass seems very simple tool but very useful for many type of field work such as measuring a shallow water depth from bridge even. (Photo/illust.-2)

2.2.4 Inflatable Boat and Outboard Engine

(1) Inflatable Boat

The main feature of inflatable boat (Photo/illust.-8) and outboard engine is as follows:

Model: BM330 mad by Brisea Marine Co.

Overall length: 330 cm

Overall width: 151 cm

Max passenger: 5

Max loading: 560 kg

Net weight: 80 kg

Photo/illust.-8 Inflatable Rubber Boat

(2) Outboard Engine (Photo/illust.-9)

Model: F15 SMHA YAMAHA

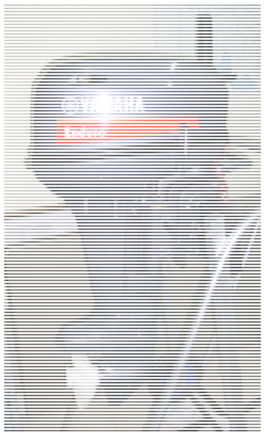
Engine type: 2 cylinders

Displacement: 362 cc

Propeller shaft horse power 15 hp @5500 rpm

Weight: 50 kg

Fuel tank: 24 L



Photo/illust.-9 Outboard Engine

(3) Boards

One board is required to mount a sounding reel (gauging winch). It has an outrigger wheel assembly. A winch board is custom-made of stainless steel. (Photo/illust.-10).

Photo/illust.-10 Winch board & sounding reel

The other one board is required to fix the the reel board on the inflatable rubber boat or bridge for flow measurement. This board is also custom-made of timber.

2.2.5 Safety Instruments

Discharge measurements are mostly work in the river. Staff has to wade or ride on the boat. Wearing a life vest and a helmet is a compulsory to all staff during the measurement work. (Photo/illust.-11).

Photo/illust.-11 Life vest

Fingers or palms will be hurt when a staff drop down a rope, cable and/or a measuring tape to the water due to friction heat. Wearing work gloves is recommended.

Further, the following material and tools will be required.

- Water proof paint (red and white color)
- Brushes (medium and thin)
- Pocket calculator

2.3 Procedure for Current Meter Measurement of Discharge

2.3.1 Selection of Site for Measurements

The first step in making a current meter measurement is to select a measurement cross section of desirable qualities. If the stream cannot be waded and high-water measurements are made from a bridge or cableway the surveyor has little or no choice with regard to selection of a measurement cross section. A site of discharge measurement can be selected taking into consideration the following characteristics:

(a) The channel at the measuring site should be straight and of uniform cross section and slope to minimize abnormal velocity distribution;

(b) Flow directions for all points on any vertical across the width should be parallel to one another and at right angles to the measurement section;

(c) A stable streambed free of large rocks, weeds and obstructions that would create eddies, slack water and turbulence;

(d) The curves of the distribution of velocities should be regular in the vertical and horizontal planes of measurement;

(e) Conditions at the section and in its vicinity should also be such as to preclude changes taking place in the velocity distribution during the period of measurement;

(f) Sites displaying vortices, reverse flow or dead water should be avoided;

(g) The measurement section should be clearly visible across its width and unobstructed by trees, aquatic growth or other obstacles;

(h) The depth of water at the section should be sufficient at all stages to provide for the effective immersion of the current meter or float, whichever is to be used;

(i) The site should be easily accessible at all times with all necessary measurement equipment;

(j) The section should be sited away from pumps, sluices and outfalls, if their operation during a measurement is likely to create flow conditions inconsistent with the natural stage-discharge relationship for the station;

(k) Sites should be avoided where there is converging or diverging flow;

(l) In those instances where it is necessary to make measurements in the vicinity of a bridge it is preferable that the measuring section be upstream of the bridge. However, in special cases and where accumulation of logs or debris is liable to occur it is acceptable that the measuring site be downstream of the bridge. Particular care should be taken in determining the velocity distribution when bridge apertures are surcharged;

(m) A measurement section that is relatively close to the gauging station control to avoid the effect of tributary inflow between the measurement section and the control, and to avoid the effect of channel storage between the measurement section and the control during periods of changing stage.

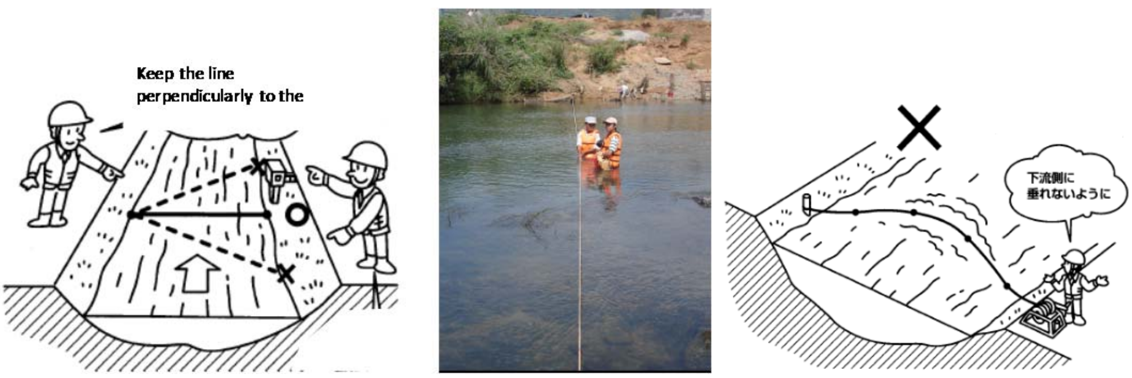
It is usually not possible to satisfy all of these conditions. Select a cross section which satisfy the above criteria as much as possible.

2.3.2 Layout and Stationing of Partial Sections and Verticals

(1) Measurement of Stream Width

After a cross section has been selected determine the width of the stream. Stretch a measuring tape/rope for measurements made by wading, from a boat, or from an unmarked bridge (Photo/illust.-12). Except for bridges, string the line at right angles to the direction of flow to avoid horizontal angles in the cross section. For bridge measurements use the graduations painted on the cable or bridge rail or curb.

If the line has a horizontal angle to the direction of flow due to some reason such as topographic condition, position of trees or posts to which the tape/rope is fixed or angle of the bridge to the direction of flow the angle has to be measured by protractor to calculate current width.



Photo/illust.-12 Stretching a rope

(2) Determination of Spacing of Verticals

Next determine the spacing of the verticals. When the cross section is smooth and with even velocity distribution, fewer partial sections may be used. Space the partial sections so that no partial section has more than 10 per cent of the total discharge. The ideal measurement is one in which no partial section has more than 5 per cent of the total discharge. Space the verticals so the discharge in each partial section is about 5 per cent of the expected total discharge from the existing rating curve.

Table 2-1 can be one of the recommendations for quick decision at working sites. This method proposes to obtain a water depth by averaging two adjacent velocity lines, not requires measurement of water depth as required in the rule of Japan (refer to section 2.1.2). The surveyor, however, can make interval of velocity line by himself taking into consideration of site condition including topography and time required for measurement.

Table 2-1 Recommended Interval of Velocity Line

Width of water surface, B	Spacing of Velocity Lines, M	The number of Velocity Lines
Less than or equal 10 m	10% to 15% of water surface	6 to 10
10 – 20 m	2 m	5 to 10
20 – 40 m	4 m	5 to 10
40 – 60 m	6 m	7 to 10
60 – 80 m	8 m	8 to 10
80 – 100 m	10 m	8 to 10
100 – 150 m	12 m	9 to 13
150 – 200 m	20 m	8 to 10
More than 200 m	30 m	8 to 15

Note: Notwithstanding the above table equal widths of partial sections across the entire cross section are not recommended unless the discharge is very evenly distributed. Make the width of the partial sections less as depths and velocities become greater.

In this method, a water depth line is calculated between two adjacent velocity lines by averaging water depth at the velocity lines as shown in Figure 2-2.

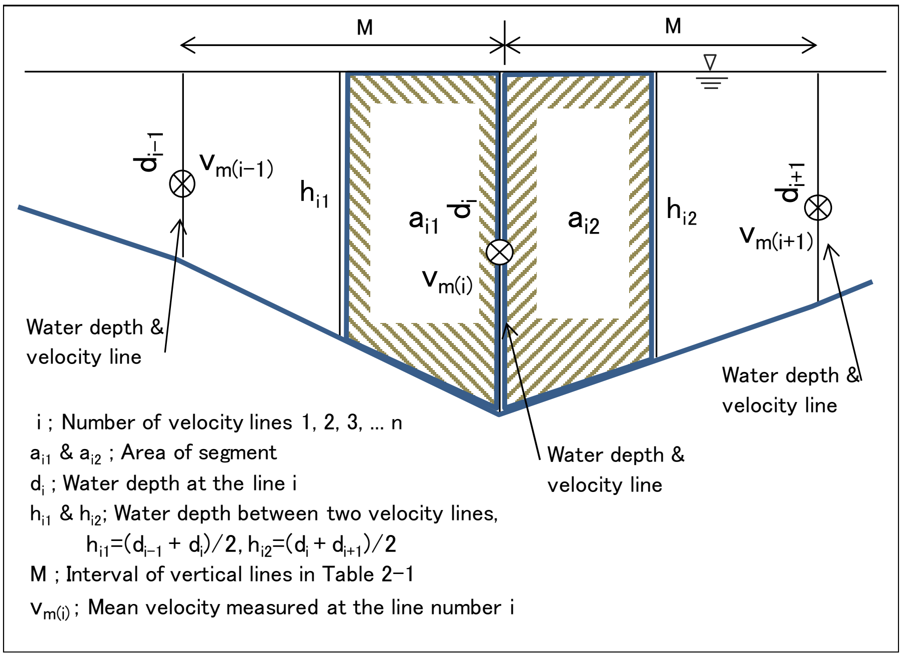


Figure 2-2 Typical Cross Sections of Two-Trapezoidal Method

A partial discharge covered by one velocity line is a summation of discharges in the two trapezoidal sections. The formula for computing the partial discharge can be obtained by the following equation.

$$q_i = (a_{i1} + a_{i2})v_{m(i)} \quad (2.3)$$

$$a_{i1} = \frac{(d_{i-1}+d_i)}{2} \times \frac{M}{2} \quad (2.4)$$

$$a_{i2} = \frac{(d_i+d_{i+1})}{2} \times \frac{M}{2} \quad (2.5)$$

Where; q_i= discharge covered by one velocity line *i*,

v_i= mean velocity at the vertical line *i*,

a_{i1} and a_{i2} = an area of two trapezoidal sections respectively adjacent to the velocity line i,

$v_{m(i)}$ = mean velocity at velocity line i,

d_i, d_{i-1}, d_{i+1} = a depth of the velocity line at i, i-1 and i+1 respectively,

M = distance between two velocity lines as shown in Table 2-1.

2.3.3 Depth Measurements

The first measurement made at a vertical is the stream depth. Depth should be measured using the proper equipment and procedures that apply to the type of measurement being made (that is wading, bridge, boat). Details of measuring depth using various equipment and under different flow conditions are described in the following section. The depth should be measured two times at each velocity line.

Photo/illust.-13 Depth Measurement from boat

2.3.4 Velocity Measurements

All staff who participate the discharge measurement have to become proficient in use of the current meter before he goes to the water.

After the depth at a velocity line is measured and recorded determine the method of velocity measurement. Several methods have been studied as discussed in the following section. Compute the setting of the meter for the particular method to be used at that depth. After the

Photo/illust.-14 Velocity Measurement

meter is placed at the proper depth let it adjust to the current before starting the velocity observation. Any meter on a cable suspension will automatically point into the current because of the effect of the meter vane. The time required for such adjustment is usually only a few seconds if the velocities are greater than about 0.3 m/sec but for lower velocities, particularly if the current meter is suspended by a cable, a longer period is needed. If the current meter is fixed to rods without the vane the current meter cannot point into the current automatically the surveyor has to rotate the rods to adjust to the direction of flow.

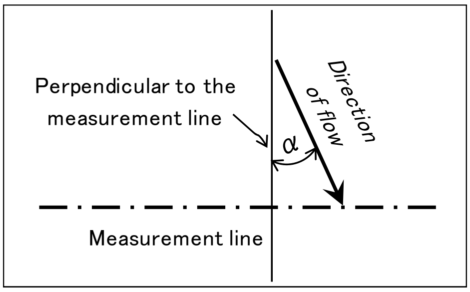


Figure 2-3 Angle Alpha in the Oblique Flow

If the meter is pointed into an oblique current the measured velocity must be multiplied by the cosine of the angle (alpha) between the current and a perpendicular to the measurement line to obtain the desired normal component of the velocity as shown in Figure 2-3.

The velocity should be measured two times at each velocity line if the water level does not change rapidly during the measurement.

2.3.5 Recording Field Notes

Field notes for a discharge measurement must be recorded either on standard paper note sheets, or by using an Electronic Field Notebook (EFN).

(1) Standard paper note keeping

Paper note sheets, as shown in Table 2-7 (a form for recording and calculating) and Table 2-8 (summary sheet), are the conventional way to record the field observations for a discharge measurement. For each measurement record the following information, at a minimum, on the front sheet of the measurement notes:

(a) Station name;
(b) Date of measurement;
(c) Time measurement at start and at end using 24 hour clock time;
(d) Gauge heights at start and at end;
(e) Control conditions such as width of water surface, number of verticals, method of velocity measurement;
(f) Pertinent information regarding the accuracy of the discharge measurement and conditions which might affect the stage-discharge relation, if any;
(g) Water levels at recorder at start and finish of measurement if possible;

On the inside notes identify the measurement starting point by either R or L (right edge of water or left edge of water, respectively, when facing downstream) and record the time that the measurement is started and ended.

Begin the measurement by recording the distance from the initial point to the edge of the water. Measure and record the depth and velocity at the edge of water. Proceed across the measurement section by measuring and recording the distance of each vertical from the initial point, the depth at the vertical, the observation depth, each velocity observation and the horizontal angle if any.

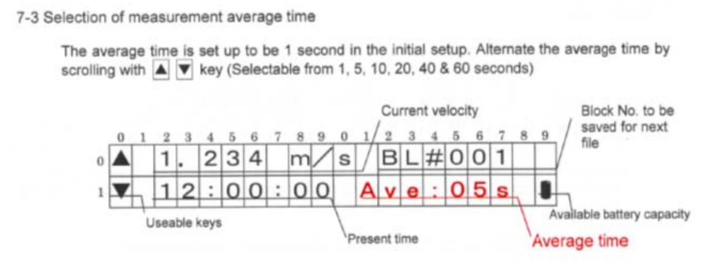
Complete all computations required for the inside form to determine the total width, area, and discharge. It is generally expected that the measurement computations will be made and the note sheets completed before the surveyor leaves the gauging station.

Erasures of original field data are not allowed. This includes items such as gauge readings, distances, depths, times, horizontal angle coefficients and other field measurements that cannot be repeated. If a variable is re-measured and it is necessary to change the originally recorded value of that variable it should be marked through and the new measurement should be recorded above or adjacent to the original. The original measurement should remain legible even though it is marked out.

(2) Electronic Field Note Book

If an electronic field notebook is used for recording field measurements and notes the same basic information is required as for paper field notes, except that much of the information is entered using the keyboard of the electronic notebook. Some data, such as time, are entered automatically and most of the measurement computations are made automatically. However, the electronic field notebooks currently available do not have the capability to receive all field data that may be required. Therefore, it is necessary to record some information on paper field form.

Each of the electronic field notebooks has different operating characteristics. Users must become familiar with how data are entered in each type to become proficient in using this type of discharge measurement recording system. User's manuals are provided with each electronic notebook. An electronic field notebook can be an efficient method to record, compute and store field notes. It provides numerous quality control features and should eliminate most arithmetic errors.

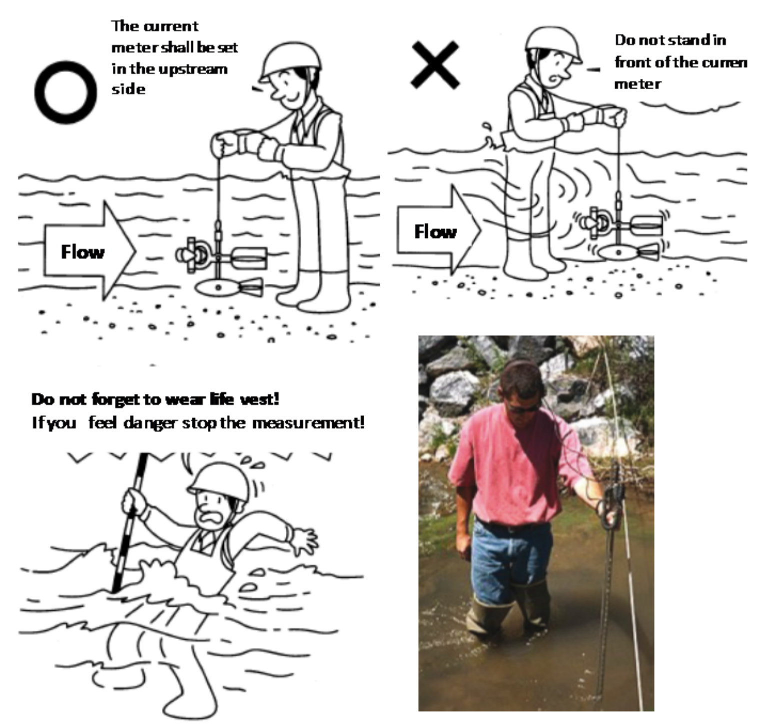


Photo/illust.-15 Display unit of AEM1-D

2.3.6 Current Meter Measurements by Wading

Current-meter measurements by wading are preferred, if conditions permit. wading measurements offer the advantage over measurements from bridges and boats in that it is usually possible to select the best of several available cross sections for the measurement. Photo/illust.-16 shows a wading measurement being made with rods.

When natural conditions for measuring are in the range considered undependable, modify the measuring cross section, if practical, to provide acceptable conditions. Often it is possible to build dikes to cut off dead water and shallow flows in a cross section, or to improve the cross section by removing the rocks and debris within the section and from the reach of stream immediately upstream from it. After modifying a cross section allow the flow to stabilize before starting the discharge measurement.



Photo/illust-16 Wading Measurement using rods

Stand in a position that least affects the velocity of the water passing the current meter. This position is usually obtained by facing the bank with the water flowing against the side of the leg. Holding the wading rod at the tag line stand from 0.03 to 0.08 m downstream from the tag line and 0.5 m or more from the wading rod. Avoid standing in the water if feet and legs would occupy a considerable percentage of the cross section of a narrow stream. In small streams where the width permits stand on a plank or other support above the water rather than in the water.

Keep the wading rod in a vertical position. Vertical axis of the current meter should be held parallel to the direction of flow while observing the velocity. Horizontal axis and the current meter should be held perpendicularly to the cross section. If the flow is not at right angles to the rope, the surveyor has to rotate the rods to adjust to the direction of flow.

During measurements of streams with shifting beds, the scoured depressions left by the surveyor's feet can affect soundings or velocities. Generally, place the meter ahead of and upstream from the feet. Record an accurate description of streambed and water-surface configuration each time a discharge measurement is made in a sand-channel stream.

2.3.7 Current Meter Measurements from Bridge

When a stream cannot be waded bridge may be used to make current-meter measurements. Many measuring sections under bridges are satisfactory for current-meter measurements. No set rule can be given for choosing the upstream or downstream side of the bridge when making a discharge measurement.

The advantages of using the upstream side of the bridge are:

(a) Hydraulic characteristics at the upstream side of bridge openings usually are more favorable. Flow is usually more smooth and there is less turbulence than at the downstream side of the bridge;

(b) Approaching drift can be seen and be more easily avoided;

(c) The streambed at the upstream side of the bridge is not likely to scour as badly as at the downstream side.

The advantages of using the downstream side of the bridge are:

(a) Vertical angles are more easily measured because the sounding line will move away from the bridge;

(b) The flow lines of the stream may be straightened out by passing through a bridge opening with piers.

The choice of using the upstream side or the downstream side of a bridge for a current-meter measurement should be decided individually for each bridge. Consideration should be given to the factors mentioned above and the physical conditions at the bridge, such as location of the walkway, traffic hazards and accumulation of trash on piles and piers.

Use either a hanging cable or a sounding reel supported by a bridge board or a portable crane to suspend the current meter and sounding weight from the bridge. Depth measurements should be made as described in the following section 2.4 Depth Measurement. Measure the velocity by setting the meter at the position in the vertical as escribed in section 2.5. Keep equipment some 1.5 m (several feet) from piers and abutments if velocities are high. Estimate the depth and velocity next to the pier or abutment on the basis of the observations at the nearest vertical.

If there are piers in the cross section it is usually necessary to use more than 25-30 partial sections to get results as reliable as those from a similar section without piers. Piers will often cause horizontal angles that must be carefully measured. Piers also cause rapid changes in the horizontal velocity distribution in the section.

The bridge pier might be excluded from the area of the measurement cross section depending primarily on the relative locations of the measurement section and the end of the pier. If measurements are made from the upstream side of the bridge it is the relative location of the upstream end (nose) of the pier that is relevant. For measurements made from the downstream side it is the location of the downstream end (tail) of the pier that is relevant. If any part of the pier extends into the measurement cross section the area of the pier is excluded. However, bridges quite commonly have cantilevered walkways from which discharge measurements are made. In that case the measurement cross section lies beyond the end of the pier (upstream from the nose or downstream from the tail, depending on which side of the bridge is used). In that situation it is the position and direction of the streamlines that determines whether or not the pier area is to be excluded. The surveyor must determine this. If there is negligible or no downstream flow in that width interval (pier subsection) then the pier is excluded. If only stagnation and/or eddy exists upstream from the nose or downstream from the tail, whichever is relevant, the area of the pier is excluded. If there is significant downstream flow in the pier subsection the area of the pier is included in the area of the measurement cross section. The horizontal angles of the streamlines in and near the pier subsection will usually be quite large in that circumstance.

Footbridges are sometimes used for measuring canals, tailraces and small streams. Rod suspension can be used from many footbridges. The procedure for determining depth in low velocities is the same as for wading measurements. For higher velocities obtain the depth by the difference in readings at an index point on the bridge when the base plate of the rod is at the water surface and on the streambed. Measuring the depth in this manner will eliminate errors caused by the water piling up on the upstream face of the rod. Hanging cables, bridge cranes and bridge boards are also used from footbridges.

Safety is a primary consideration when making discharge measurements from bridges. High-speed traffic can present a major safety hazard and it is no longer recommendable to make discharge measurements from some busy traffic bridges, such as those on National Road. All safety precautions, such as the use of cones, traffic signs and flag-persons should be employed.

2.3.8 Current Meter Measurements from Boat

Discharge measurements are made from boats where no cableways or suitable bridges are available and where the stream is too deep to wade. Personal safety is the limiting factor in the use of boats on streams having high velocity.

For boat measurements, the cross section should be selected so that it has attributes similar to those described in a previous section 2.3.1. Depth is of no consideration in a boat measurement because if the stream is too shallow to float a boat the stream can usually be waded. However, velocity in the measurement section is an important concern. If velocities are too slow, meter registration may be affected by an oscillatory movement of the boat in which the boat (even though fastened to a tag line) moves upstream and downstream as a result of wind action. Also, vertical movement of the boat as a result of wave action may affect a vertical-axis current meter. If velocities are too fast it becomes difficult to string a tag line across the stream.

Photo/illust-17 Measurement from boat

If a rope is feasible for use in making a boat measurement, stretch the rope at the measuring section by extending the rope as the boat moves across the stream. After a rope has been stretched across the stream, take up the slack by tackling the rope and to tie with an anchored support or a foot of sturdy trees on the bank.

If there is traffic on the river one person must be stationed on the bank to lower or raise the rope to allow the river traffic to pass. Place streamers on the rope so that it is visible to boat pilots. If there is a continual flow of traffic on the river, or if the width of the river is too great to stretch a rope, other means will be needed to position the boat. Night measurements by boat are not recommended because of the safety aspect.

When no tag line is used, the boat can be kept in the cross section by lining up with flags positioned on each end of the cross section, as illustrated in Figure 2-4. Flags on one bank would suffice but it is better to have them on both banks. The position of the boat in the cross section can be determined by a transit on the shore and a stadia rod (levelling rod) held in the boat.

Another method of determining the position of the boat is by setting a transit on one bank some convenient known distance from and at right angles to the cross-section line. The position of the boat is determined by measuring the angle α to the boat, measuring the distance CE and computing the distance MC as shown in Figure 2-5.

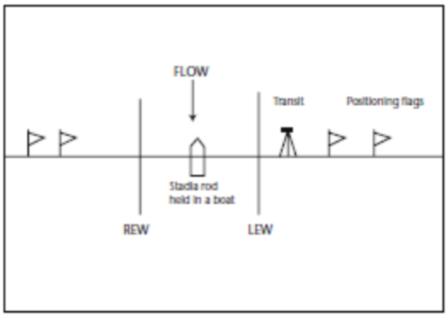


Figure 2-4 Determination of the position in a cross section using the stadia method

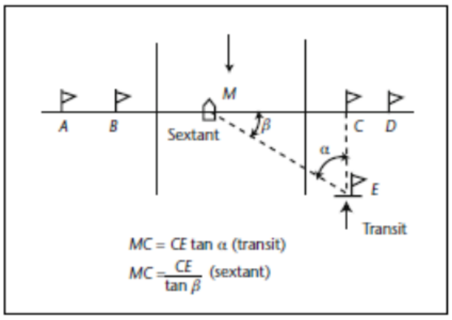


Figure 2-5 Determination of the position in a cross section using the angular method

Boat position can also be determined by using the Global Positioning System (GPS) with Differential Corrections (DGPS). This method is especially useful on very wide streams and in flood plains where other methods of determining boat position are not applicable.

Unless anchoring is more convenient, the motor must hold the boat stationary when depth and velocity readings are being taken.

Boat measurements are not recommended at velocities less than 0.3 m/sec when the boat is subject to wave action. The up-and-down movement of the boat (and the meter) seriously affects the velocity observations. If the maximum depth in the cross section is less than 3 m and the velocity is low, use a rod for measuring the depth and for supporting the current meter. For greater depths and velocities use a cable suspension with a reel and sounding weight.

2.4 Measurement of Water Depth

2.4.1 By Leveling Staff Gauge

A leveling staff gauge can be used for measurement of stream depth when the water is shallow enough for making a wading measurement, from boat, or when the measurement can be made from a low foot bridge or other structure which will support the observer over the stream.

Attention is to be paid in depth measurement by a leveling staff in the natural river or canal of which streambed is mud or other soft type soil since the staff will sink into streambed.

2.4.2 By Wading Rods

Two wading rods can be used for measurement of stream depth when the water is shallow enough for making a wading measurement or when the measurement can be made from a low foot bridge or other structure which will support the observer over the stream.

2.4.3 By Sounding Reel and Cable

(1) Measurement by an Indicator

Water depth is measured with sounding cable of current meter and weights when the depth is too large for use of a leveling staff gauge or wading rod, and when measuring conditions require that measurements be made from a bridge or boat.

The size of the sounding weight used in current-meter measurements depends on the depth and velocity to be found in a cross section. A rule of thumb is that the size of the sounding weight (in kilograms) should be greater than 5 times the maximum product of velocity (in m/sec) and depth (in m) in the cross section. If insufficient weight is used the sounding line will be dragged at an angle downstream. If debris is flowing or if the stream is shallow and fast a heavier weight should be used. The rule is not rigid but does provide a starting point for deciding on the size of the weight necessary. Examine notes of previous measurements at a site to help determine the size of the weight needed at various stages.

Attention is to be paid when depth measurement is made by sounding cable with weight. The operator must feel carefully when the weight touches the streambed. If the velocity of flow is high, the sounding weight and cable drift to downstream resulting in larger depth than real one. Corrections are to be made as described hereunder. Another attention is to be paid depth measurement by sounding cable in the natural river or canal of which streambed is mud or other soft type soil since the weight will sink into streambed.

The sounding reel is equipped with a depth indicator. The number of depth indicator is to be observed and recorded when the center of the current meter sensor is at the water surface. Lower the sounding weight and current meter until the weight touches the streambed, and read the indicated number. Calculate the difference of the two numbers, and add the distance that the meter is mounted above the bottom of the weight (distance of suspension). For example, if 0.80 m is indicated when the current meter sensor is at the water surface and 2.64 m is indicated when the sounding weight touches the streambed, the depth of water is:

2.64-0.80+0.16=2.00 m

Where, 0.16 m is the suspension from sensor to bottom of weight for example

To move the meter to the 0.8-depth position merely raise the weight and the current meter until the pointer is at the 2.40 m-mark on the indicator, which correspond to 1.60 m of the water depth (=0.8×2.00). To set the meter at the 0.2-depth position raise the weight and meter until the pointer is at 1.20 m on the indicator which corresponds to 0.40 m of water depth (0.2×2.00) as shown below.

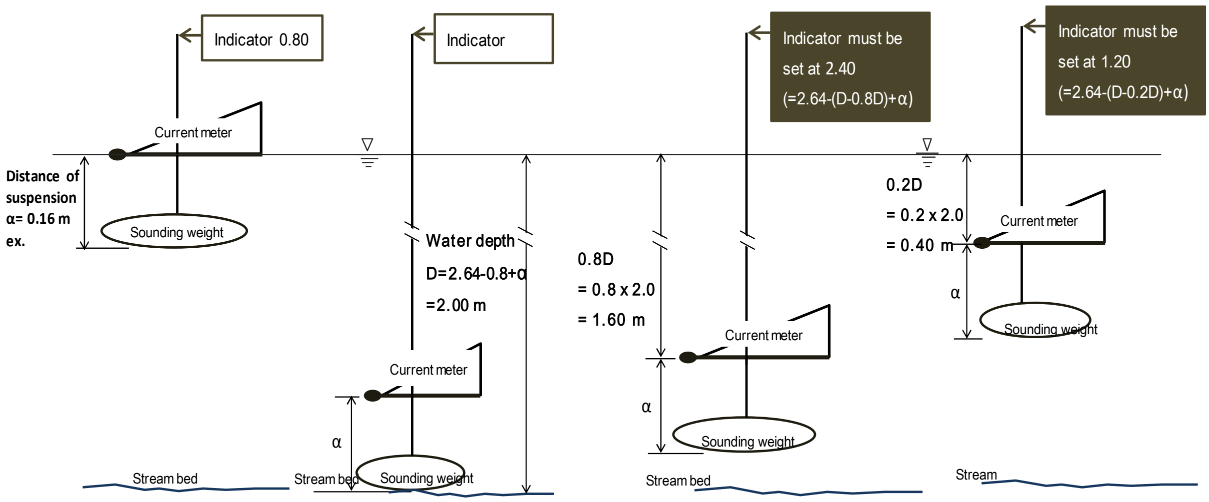


Figure 2.6 Measurement of Water Depth by Sounding Weight and Cable

(2) Depth corrections for downstream drift of current meter and weight

Where it is possible to sound but the weight and meter drift downstream, the depths measured by the usual methods are too large. Figure 2-7 graphically illustrates this condition. The correction for this error has two parts: the air correction and the wet-line correction. The air correction is shown as the distance, *c-d* shown in Figure 2-7. The wet-line correction is shown as the difference between the wet-line depth *d-e* and the vertical depth, *d-g*.

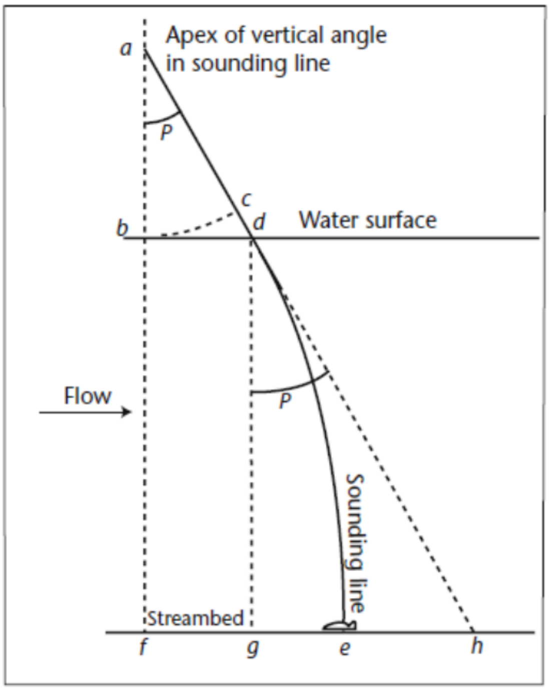


Figure 2-7 Typical Sounding Line by Downstream Drift

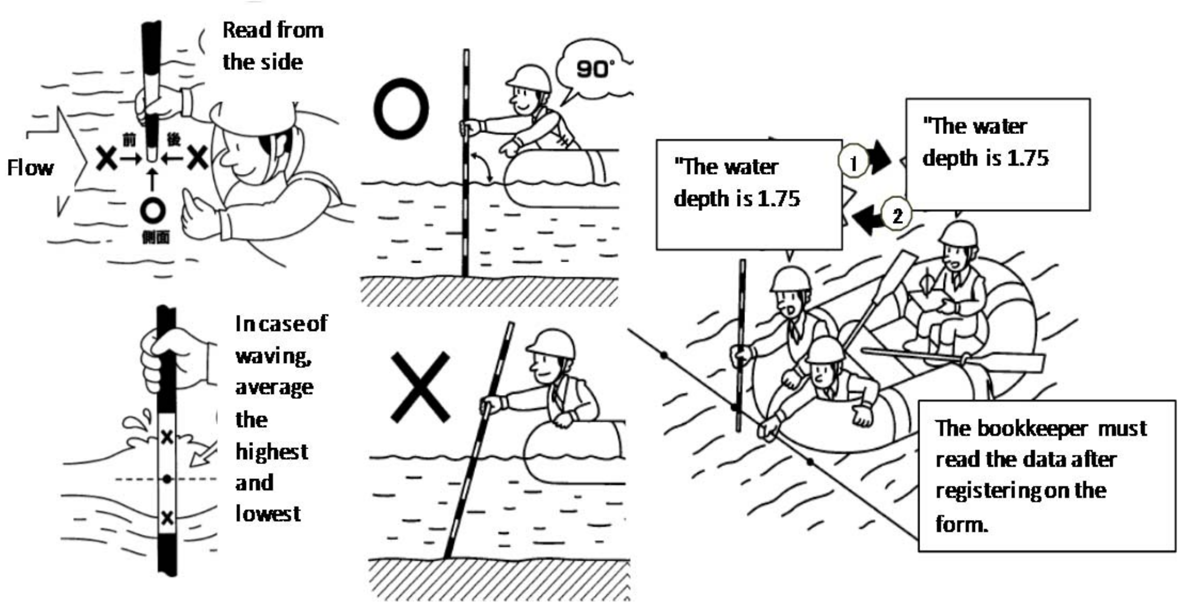
The air correction, *c-d* for selected vertical angles between 5 degrees and 35 degrees and vertical lengths between 1 and 20 m is shown in Table 2-2.

The wet-line correction, *d-g* for angles between 10 degrees and 35 degrees and wet-line depths between 1 m and 20 m is shown in Table 2-3. The wet-line correction cannot be determined until the air correction has been deducted from the observed depth.

2.4.4 By Measuring Tape

Water depth is measured with measuring tape (50 m) when no staff gauge nor sounding reel is available, and when measuring conditions require that measurements be made from a bridge or boat.

The procedure of this method is similar to the measuring by sounding reel discussed in the previous section except that the tape may be dropped by hand. The correction of depth has to be made as shown in Tables 2-3 and 2-4.



Photo/illust.-18 Attentions Required for Measurement of Water Depth

Table 2-2 Air correction table, giving differences, in meters, between vertical length and slant length of sounding line above water surface for selected vertical angles

Vertical length in metres	*Vertical angle of sounding line at protractor (degrees)*																										
	5	*8*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*
1	0.00	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.08	0.09	0.09	0.10	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.19	0.21	0.22
2	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.13	0.14	0.16	0.17	0.19	0.21	0.22	0.24	0.26	0.29	0.31	0.33	0.36	0.38	0.41	0.44
3	0.01	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.12	0.14	0.16	0.17	0.19	0.21	0.24	0.26	0.28	0.31	0.34	0.37	0.40	0.43	0.46	0.50	0.54	0.58	0.62	0.66
4	0.02	0.04	0.06	0.07	0.09	0.11	0.12	0.14	0.16	0.18	0.21	0.23	0.26	0.28	0.32	0.34	0.38	0.42	0.45	0.49	0.53	0.57	0.62	0.67	0.72	0.77	0.82	0.88
5	0.02	0.05	0.08	0.09	0.11	0.14	0.16	0.18	0.20	0.23	0.26	0.29	0.32	0.35	0.40	0.43	0.47	0.52	0.56	0.61	0.66	0.72	0.78	0.84	0.90	0.96	1.03	1.10
6	0.00	0.05	0.10	0.10	0.15	0.15	0.20	0.20	0.25	0.30	0.30	0.35	0.40	0.45	0.45	0.50	0.55	0.60	0.65	0.75	0.80	0.85	0.95	1.00	1.05	1.15	1.25	1.35
7	0.05	0.05	0.10	0.15	0.15	0.20	0.20	0.25	0.30	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.75	0.80	0.85	0.90	1.00	1.10	1.15	1.25	1.35	1.45	1.55
8	0.05	0.10	0.10	0.15	0.20	0.20	0.25	0.30	0.35	0.35	0.40	0.45	0.50	0.55	0.65	0.70	0.75	0.85	0.90	1.00	1.05	1.15	1.25	1.35	1.45	1.55	1.65	1.75
9	0.05	0.10	0.15	0.15	0.20	0.25	0.30	0.30	0.35	0.40	0.45	0.50	0.60	0.65	0.70	0.75	0.85	0.95	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.75	1.85	2.00
10	0.05	0.10	0.15	0.20	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.65	0.70	0.80	0.85	0.95	1.05	1.10	1.20	1.30	1.45	1.55	1.65	1.80	1.90	2.05	2.20
11	0.0	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.8	2.0	2.1	2.3	2.4
12	0.0	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.8	1.0	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0	2.2	2.3	2.5	2.6
13	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.9	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.7	1.9	2.0	2.2	2.3	2.5	2.7	2.9
14	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.9	3.1
15	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.8	2.0	2.1	2.3	2.5	2.7	2.9	3.1	3.3
16	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.5	2.7	2.3	3.1	3.3	3.5
17	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.8	1.9	2.1	2.2	2.4	2.6	2.8	3.0	3.3	3.5	3.8
18	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.2	1.3	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.5	3.7	4.0
19	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.8	2.0	2.1	2.3	2.5	2.7	2.9	3.2	3.4	3.6	3.9	4.2
20	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.2	2.4	2.6	2.9	3.1	3.3	3.6	3.8	4.1	4.4

Table 2-3 Wet-line table, giving difference, in meters, between wet-line length and vertical depth for selected vertical angles

Wet-line length in metres	*Vertical angle of sounding line at protractor (degrees)*																									
	10	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***	***28***	***29***	***30***	***31***	***32***	***33***	***34***	***35***
1	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.09	0.10	0.10	0.11	0.12	0.12
2	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.08	0.08	0.09	0.09	0.10	0.11	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19
3	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.08	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.18	0.19	0.20	0.21	0.23	0.24	0.26	0.27
4	0.03	0.04	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.19	0.21	0.22	0.24	0.25	0.27	0.28	0.30	0.32	0.34
5	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.17	0.18	0.20	0.22	0.24	0.26	0.27	0.29	0.31	0.33	0.35	0.38	0.40	0.42
6	0.05	0.05	0.05	0.05	0.10	0.10	0.10	0.10	0.15	0.15	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.30	0.30	0.35	0.35	0.40	0.40	0.45	0.45	0.50
7	0.05	0.05	0.05	0.10	0.10	0.10	0.10	0.15	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.30	0.30	0.35	0.35	0.40	0.40	0.45	0.50	0.50	0.55	0.55
8	0.05	0.05	0.10	0.10	0.10	0.10	0.15	0.15	0.15	0.20	0.20	0.25	0.25	0.30	0.30	0.35	0.35	0.40	0.40	0.45	0.45	0.50	0.55	0.55	0.60	0.65
9	0.05	0.10	0.10	0.10	0.10	0.15	0.15	0.20	0.20	0.20	0.25	0.25	0.30	0.30	0.35	0.35	0.40	0.45	0.45	0.50	0.55	0.55	0.60	0.65	0.70	0.70
10	0.05	0.10	0.10	0.10	0.15	0.15	0.15	0.20	0.20	0.25	0.25	0.30	0.30	0.35	0.35	0.40	0.45	0.45	0.50	0.55	0.60	0.60	0.65	0.70	0.75	0.80
11	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.9
12	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9
13	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0
14	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1
15	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2
16	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2
17	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3
18	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4
19	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.1	1.2	1.2	1.3	1.4	1.5
20	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6

2.5 Measurement of Velocity

2.5.1 General

A current meter generally measures stream velocity at a point. The method of making discharge measurements at a cross section by using a current meter that measures point velocities requires selected verticals. The velocity in a vertical varies from surface to bottom as shown Figure 2-8. The mean velocity in a vertical is obtained from velocity observations at several points in that vertical. The mean velocity can be approximated by making a few velocity those velocities and the mean in the vertical. The various methods of measuring velocity are:

(a) One-point method;

(b) Two-point method;

(c) Two-tenths method;

(d) Three-point method;

(e) Five-point method;

(f) Subsurface method

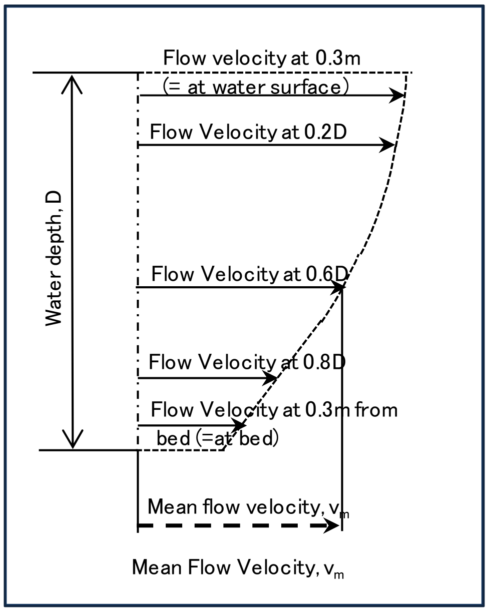


Figure 2-8 Typical Vertical-velocity Curve

2.5.2 One-point Method

The one-point method consists of measuring the velocity at 0.6 of the depth from the water surface and is generally used for shallow flows where the two-point method is not applicable. The method gives satisfactory results.

The mean velocity can be obtained by the following equation:

$$v_m = v_{0.6D} \qquad (2.6)$$

Where, v_m=mean velocity, v_{062D}=velocity at 0.6-depth

2.5.3 Two-point Method

In the two-point method of measuring velocities, observations are made in each vertical at 0.2 and 0.8 of the depth below the surface. The average of these two observations is used as the mean velocity in the vertical. This method is based on many studies of actual observation and on mathematical theory. Experience has shown that this method gives more consistent and accurate results than any of the other methods except for the vertical-velocity curve method. On average, the two-point method gives results that are within one percent of the true mean velocity in the vertical if the vertical velocity curve is substantially parabolic in shape.

The two-point method is generally used for depths of 0.6 m or greater. The two-point method is not used at depths less than 0.6 m because the current meter would be too close to the water surface and to the streambed to give dependable results. A rough test of whether or not the velocities at the 0.2- and 0.8-depths are sufficient for determining mean vertical velocity is given in the following criterion: the 0.2-depth velocity should be greater than the 0.8-depth velocity but less than twice as great.

The mean velocity can be obtained by the following equation:

$$v_m = (v_{0.2D} + v_{0.8D})/2 \qquad (2.7)$$

Where, v_m=mean velocity, D=water depth, $v_{0.2D}$=velocity at 0.2-depth, $v_{0.8D}$=velocity at 0.8-depth

2.5.4 Two-tenth Method

The two-tenths-depth method consists of observing the velocity at 0.2 of the depth below the surface and applying a coefficient to this observed velocity to obtain the mean in the vertical. It is used mainly during times of high water when the velocities are great, making it impossible to obtain soundings or to place the meter at the 0.8- or 0.6-depth.

Actual observations and mathematical theory has shown that the 0.6-depth method gives reliable results as shown in Table 2-4

Table 2-4 Coefficients to Obtain Mean Velocity from Various Depth of Observation

Ratio of observation depth to depth of water	Coefficient to obtain mean velocity
0.05	0.862
0.1	0.862
0.2	0.870
0.3	0.885
0.4	0.903
0.5	0.937
0.6	0.980
0.7	1.049
0.8	1.148
0.9	1.34
0.95	1.543

For example, the mean velocity can be obtained by:

$$v_m = 0.87 \times v_{0.2D} \qquad (2.8)$$

Where, v_m=mean velocity, $v_{0.2D}$=velocity at 0.2-depth

2.5.5 Three-point Method

The three-point method consists of observing the velocity at 0.2, 0.6 and 0.8 of the depth, thereby combining the two-point and six-tenth methods. The preferred method of computing the mean velocity is to average the 0.2- and 0.8-depth observations and then average this result with the 0.6-depth observation. However, when more weight to the 0.2- and 0.8-depth observations is desired, the arithmetical mean of the three observations may be used. The three-point method is used when the velocities in the vertical are abnormally distributed. It is also used when the 0.8-depth observation is made where the velocity is seriously affected by friction or by turbulence produced by the streambed or an obstruction in the stream. The depths must be larger than 0.75 m before this method can be used.

The mean velocity can be obtained by:

$$v_m = (v_{0.2D} + 2 \times v_{0.6D} + v_{0.8D})/4 \qquad (2.9)$$

2.5.6 Five-point Method

Velocity observations are made in each vertical at 0.2, 0.6 and 0.8 of the depth below the surface, and as close to the surface and to the stream-bed as practical.

The mean velocity may be computed from the equation:

$$v_m = 0.1 \times (v_{surface} + 3v_{0.2D} + 3v_{0.6D} + 2v_{0.8D} + v_{bed}) \qquad (2.10)$$

2.5.7 Subsurface Method

This method may be called Water Surface Method in some regions. The subsurface method involves measuring the velocity near the water surface and then multiplying it by a coefficient ranging from 0.85 to 0.95, depending on the depth of water, the velocity, and the nature of the stream or canal bed. The difficulty of determining the exact coefficient limits the usefulness and accuracy of this method.

2.5.8 Selection of Methods

The above methods should be selected adequately during field work taking into consideration the water depth and flow condition if the water level appears to be changing or stable. The suggestion is presented in the following table.

Table 2-5 Selection of Methods for Obtaining Mean Velocity at a Vertical Line

Method	Applicable range of water depth, D	Ratio of observation depth to depth of water	Equation to obtain mean velocity, v_m
One point method (Six-tenth method)	$0.3\ m < D \leqq 0.6\ m$	0.6D	$v_m = v_{0.6D}$
2-point method	$0.6\ m < D \leqq 3.0\ m$	0.2D and 0.8D	$v_m = (v_{0.2D} + v_{0.8D})/2$
Two-tenth method	$0.6\ m < D \leqq 3.0\ m$ if it is impossible to place the meter at the 0.8D or 0.6D due to high velocity	0.2D	$v_m = 0.87 v_{0.2D}$
3-point method	$3.0\ m < D \leqq 6.0\ m$	0.2D, 0.6D and 0.8D	$v_m = (v_{0.2D} + 2 \times v_{0.6D} + v_{0.8D})/4$
5-point method	$6.0\ m < D$	0.3 m, 0.2D, 0.6D, 0.8D and 0.3m from bed	$v_m = 0.1(v_s + 3v_{0.2D} + 3v_{0.6D} + 2v_{0.8D} + v_{bed})$
Subsurface method	$D \leqq 0.3\ m$	$\leqq$ 0.3 m	$v_m = 0.87 v_s$

As shown in above table, three kind of water depth are to be calculated during the field work to determine observation depth of current meter. A chart is prepared for quick reference of observation depth as shown in Table 2-6.

2.6 Calculation of Flow

After finishing measurement of velocity each vertical the mean velocity are to be calculated at each vertical. The following FORMs are available in the server computer:

- FORM-33 Two-tenth (0.2D) Method ($0.6\ m<D\leqq 3\ m$, $v_m=0.87v_{0.2D}$)
- FORM-34 2-point Method ($0.6\ m<D\leqq 3\ m$, $v_m=(v_{0.2D}+v_{0.8D})/2$) and/or 3-point Method ($3.0\ m<D\leqq 6.0\ m$, $v_m= (v_{0.2D}+2\times v_{0.6D}+v_{0.8D})/4$)
- FORM-35 5-point Method ($6.0\ m<D$) including 1-point ($v_m=v_{0.6D}$), 2-point ($v_m=(v_{0.2D}+v_{0.8D})/2$ and 3-point ($v_m=(v_{0.2D}+2\times v_{0.6D}+v_{0.8D})/4$) methods
- FORM-36 For Float Method in Flood Time
- FORM-37 Discharge Measurement Note
- FORM-41 Calculation of Discharge by Applying H-Q Curves
- FORM-42 Daily mean, Monthly Mean and Annual Mean Discharges

Table 2-7 presents sample calculation of mean velocity at every vertical line, areas and discharges between two vertical lines. A summation of discharges is a total discharge in the river at the measurement time.

Table 2-6 Charts for Determining Depth of Current Meter at 0.2D, 0.6D and 0.8D

ex. Water depth, D=1.45 m seeing the chart below obtain 0.2D=0.29 m and 0.8D=1.16 m

Chart for 20% of water depth (0.2D)

	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	
0.													0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	**0.**
1.	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	**1.**
2.	0.40	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	**2.**
3.	0.60	0.61	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.70	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	**3.**
4.	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	**4.**
5.	1.00	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19	**5.**
6.	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	**6.**
7.	1.40	1.41	1.42	1.43	1.44	1.45	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.56	1.57	1.58	1.59	**7.**
8.	1.60	1.61	1.62	1.63	1.64	1.65	1.66	1.67	1.68	1.69	1.70	1.71	1.72	1.73	1.74	1.75	1.76	1.77	1.78	1.79	**8.**
9.	1.80	1.81	1.82	1.83	1.84	1.85	1.86	1.87	1.88	1.89	1.90	1.91	1.92	1.93	1.94	1.95	1.96	1.97	1.98	1.99	**9.**
10.	2.00	2.01	2.02	2.03	2.04	2.05	2.06	2.07	2.08	2.09	2.10	2.11	2.12	2.13	2.14	2.15	2.16	2.17	2.18	2.19	**10.**

Chart for 60% of water depth (0.6D)

	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	
0.							0.18	0.21	0.24	0.27	0.30	0.33	0.36	0.39	0.42	0.45	0.48	0.51	0.54	0.57	**0.**
1.	0.60	0.63	0.66	0.69	0.72	0.75	0.78	0.81	0.84	0.87	0.90	0.93	0.96	0.99	1.02	1.05	1.08	1.11	1.14	1.17	**1.**
2.	1.20	1.23	1.26	1.29	1.32	1.35	1.38	1.41	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.68	1.71	1.74	1.77	**2.**
3.	1.80	1.83	1.86	1.89	1.92	1.95	1.98	2.01	2.04	2.07	2.10	2.13	2.16	2.19	2.22	2.25	2.28	2.31	2.34	2.37	**3.**
4.	2.40	2.43	2.46	2.49	2.52	2.55	2.58	2.61	2.64	2.67	2.70	2.73	2.76	2.79	2.82	2.85	2.88	2.91	2.94	2.97	**4.**
5.	3.00	3.03	3.06	3.09	3.12	3.15	3.18	3.21	3.24	3.27	3.30	3.33	3.36	3.39	3.42	3.45	3.48	3.51	3.54	3.57	**5.**
6.	3.60	3.63	3.66	3.69	3.72	3.75	3.78	3.81	3.84	3.87	3.90	3.93	3.96	3.99	4.02	4.05	4.08	4.11	4.14	4.17	**6.**
7.	4.20	4.23	4.26	4.29	4.32	4.35	4.38	4.41	4.44	4.47	4.50	4.53	4.56	4.59	4.62	4.65	4.68	4.71	4.74	4.77	**7.**
8.	4.80	4.83	4.86	4.89	4.92	4.95	4.98	5.01	5.04	5.07	5.10	5.13	5.16	5.19	5.22	5.25	5.28	5.31	5.34	5.37	**8.**
9.	5.40	5.43	5.46	5.49	5.52	5.55	5.58	5.61	5.64	5.67	5.70	5.73	5.76	5.79	5.82	5.85	5.88	5.91	5.94	5.97	**9.**
10.	6.00	6.03	6.06	6.09	6.12	6.15	6.18	6.21	6.24	6.27	6.30	6.33	6.36	6.39	6.42	6.45	6.48	6.51	6.54	6.57	**10.**

Chart for 80% of water depth (0.8D)

	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	
0.													0.48	0.52	0.56	0.6	0.64	0.68	0.72	0.76	**0.**
1.	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.48	1.52	1.56	**1.**
2.	1.60	1.64	1.68	1.72	1.76	1.80	1.84	1.88	1.92	1.96	2.00	2.04	2.08	2.12	2.16	2.20	2.24	2.28	2.32	2.36	**2.**
3.	2.40	2.44	2.48	2.52	2.56	2.60	2.64	2.68	2.72	2.76	2.80	2.84	2.88	2.92	2.96	3.00	3.04	3.08	3.12	3.16	**3.**
4.	3.20	3.24	3.28	3.32	3.36	3.40	3.44	3.48	3.52	3.56	3.60	3.64	3.68	3.72	3.76	3.80	3.84	3.88	3.92	3.96	**4.**
5.	4.00	4.04	4.08	4.12	4.16	4.20	4.24	4.28	4.32	4.36	4.40	4.44	4.48	4.52	4.56	4.60	4.64	4.68	4.72	4.76	**5.**
6.	4.80	4.84	4.88	4.92	4.96	5.00	5.04	5.08	5.12	5.16	5.20	5.24	5.28	5.32	5.36	5.40	5.44	5.48	5.52	5.56	**6.**
7.	5.60	5.64	5.68	5.72	5.76	5.80	5.84	5.88	5.92	5.96	6.00	6.04	6.08	6.12	6.16	6.20	6.24	6.28	6.32	6.36	**7.**
8.	6.40	6.44	6.48	6.52	6.56	6.60	6.64	6.68	6.72	6.76	6.80	6.84	6.88	6.92	6.96	7.00	7.04	7.08	7.12	7.16	**8.**
9.	7.20	7.24	7.28	7.32	7.36	7.40	7.44	7.48	7.52	7.56	7.60	7.64	7.68	7.72	7.76	7.80	7.84	7.88	7.92	7.96	**9.**
10.	8.00	8.04	8.08	8.12	8.16	8.20	8.24	8.28	8.32	8.36	8.40	8.44	8.48	8.52	8.56	8.60	8.64	8.68	8.72	8.76	**10.**

Table 2-7 Recording and Calculating Form for Discharge Measurement

Discharge Measurement FORM-34

1-point (0.3m<D<=0.6m, $v_m=v_{0.6D}$), 2-point (0.6m<D≦3m, $v_m=(v_{0.2D}+v_{0.8D})/2$) and/or 3-point (3.0m<D≦6.0m, $v_m= ((v_{0.2D}+2\times v_{0.6D}+v_{0.8D})/4)$ Methods

Station: Bak Trakoun **Date:** 2015/9/9 **Time:** 15:37 **to** 17:20 **WL:** 0.87 **to** 0.90

No.	Cumulative distance of vertical line (m)	Remark ex. end of water surface, column of bridge, island, etc.	Angle between flow and tag line, A (°)	Angle between vertical line and current meter, B (°)	Water depth (m) 1st time	Water depth (m) 2nd time	Measure. point from water surface (m) 0.2D 1st time	0.2D 2nd time	0.6D 1st time	0.6D 2nd time	0.8D 1st time	0.8D 2nd time	Flow Velocity (m/sec) 0.2D 1st time	0.2D 2nd time	0.6D 1st time	0.6D 2nd time	0.8D 1st time	0.8D 2nd time	Vave (m/s)	cos(A)	Vave adjusted by cos(A) (m)
R or L																					
0	8.80	Edge of water	0.0		0.00															1.000	0.000
1	10.50		0.0		0.51				0.306						0.278				0.278	1.000	0.278
2	12.00		0.0		0.96		0.19				0.77		0.276				0.261		0.269	1.000	0.269
3	18.00		0.0		1.30		0.28				1.04		0.306				0.217		0.262	1.000	0.262
4	22.14	Edge of water	0.0		1.01		0.20				0.80		0.024				0.000		0.012	1.000	0.012
		Footing of column																			
5	24.88	Edge of water			1.44		0.29				1.15		0.000				0.303		0.152	1.000	0.152
6	33.00		0.0		3.01		0.60				2.41		0.535				0.367		0.451	1.000	0.451
7	40.50		0.0		2.50		0.50				2.00		0.384				0.335		0.360	1.000	0.360
8	46.00	Edge of water			1.62		0.32				1.30		0.035				0.282		0.159	1.000	0.159
		Footing of column																			
9	49.00	Edge of water			1.63		0.33				1.30		0.000				0.232		0.116	1.000	0.116
10	55.00		0.0		1.19		0.24				0.95		0.000				0.000		0.000	1.000	0.000
11	70.00	Edge of water			0.61				0.37						0.000				0.000	1.000	0.000
		Footing of column																			
12	72.70	Edge of water			0.61				0.37						0.000				0.000	1.000	0.000
13	79.40	Edge of water	0.0		0.00																
14																					
R or L																					
Total or average					1.17	#DIV/0!							0.17	#DIV/0!	0.09	#DIV/0!	0.22	#DIV/0!	0.171		0.158
Observer:				Calculater:					Note:												

Discharge Measurement FORM-34

Bak Trakoun **Date:** 2015/9/9

Adjustment of water depth by the angle between vertical line and current meter

No.	1st measurement: Angle B & Table 2-2 for air adjust.	Air adjusted	Angle B & Table 2-3 for wet line adjust,	Wet line adjusted	2nd measurement: Angle B & Table 2-2 for air adjust.	Air adjusted	Angle B & Table 2-3 for wet line adjust,	Wet line adjusted	Dave., depth at velocity line (m)	Distance W (m)	Distance 0.5W (m)	Depth for calcu. (m)	Section area ⊿S (m2)	Section area S (m2)	Q (m3/s)
R or L															
0		0.00		0.00					0.00		0.85	0.000	0.108	0.108	0.000
										1.70	0.85	0.255	0.325		
1		0.51		0.51					0.51		0.75	0.510	0.467	0.792	0.220
										1.50	0.75	0.735	0.636		
2		0.96		0.96					0.96		3.00	0.960	3.135	3.771	1.012
										6.00	3.00	1.130	3.645		
3		1.30		1.30					1.30		2.07	1.300	2.541	6.186	1.618
										4.14	2.07	1.155	2.241		
4		1.01		1.01					1.01		0.00	1.010	0.000	2.241	0.027
											0.00	1.225	0.000		
5		1.44		1.44					1.44		4.06	1.440	7.440	7.440	1.127
										8.12	4.06	2.225	10.627		
6		3.01		3.01					3.01		3.75	3.010	10.809	21.436	9.668
										7.50	3.75	2.755	9.853		
7		2.50		2.50					2.50		2.75	2.500	6.270	16.123	5.796
										5.50	2.75	2.060	5.060		
8		1.62		1.62					1.62		0.00	1.620	0.000	5.060	0.802
											0.00	1.625	0.000		
9		1.63		1.63					1.63		3.00	1.630	4.560	4.560	0.529
										6.00	3.00	1.410	3.900		
10		1.19		1.19					1.19		7.50	1.190	7.838	11.738	0.000
										15.00	7.50	0.900	5.663		
11		0.61		0.61					0.61		0.00	0.610	0.000	5.663	0.000
											0.00	0.610	0.000		
12		0.61		0.61					0.61		3.35	0.610	1.533	1.533	0.000
										6.70	3.35	0.305	0.511		
13		0.00		0.00					0.00		0.00	0.000	0.000	0.511	0.000
											0.00	0.000	0.000		
14											0.00		0.000	0.000	0.000
											0.00		0.000		
R or L											0.00			0.000	0.000
Total or average	#DIV/0!	1.17	#DIV/0!	1.17	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.17	62.16	62.16	1.171	87.161	87.161	20.799

The cells not shadowed are for input primary data. Attention has to be paid not to change unnecessarily the cells shadowed which contain functions. Spread sheets of the FORMs are available in the server computer.

Table 2.8 Discharge Measurement Note

FORM-37 Discharge Measurement Note

Code of station: ______________________

Name of station: ______________________ Name of river: ______________________

Date (dd/mm/yyyy): ______________________

Member of measurement: ______________________

______________________ ______________________

______________________ ______________________

______________________ ______________________

Type of measurement; (1) Current meter AEM1-D, (2) Float, (3) ______

Method: (1) Wading, (2) Bridge, (3) Boat, ______

Time of measurement: Start at ____ hr. ____ min. - Finish at ____ hr. ____ min.

G.H. at start: ____ m G.H. at the end: ____ m

______________________ ______________________

Width of water surface in meter: ____ m

Number of verticals: ______________________

Method of velocity measur.: (1) 1-point, (2) 2-point, (3) 3-point, (4) Other method ______

Vertical angle (for air correction): ____ ° Coeff.: ______

Vertical angle (for wet-line correction): ____ ° Coeff.: ______

Horizontal angle: ____ ° cos α : ______

Total discharge: ____ m^3/sec

Total water area: ____ m^2

Average velocity: ____ m/sec

Weather: ______________________

Flow: (1) Slow, (2) Rapid but smooth, (3) Rapid with turbulance ______

Water level at recorder at start: ____ m Date of check the recorder ______

Water level at recorder at finish: ____ m

Checked by: ______________________

Date: ______________________

Remarks: ______________________

____

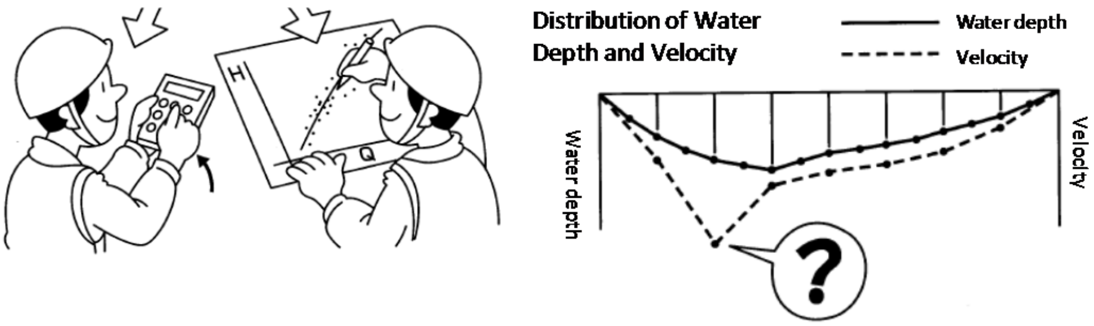
____

FORM-37 is available in the server computer.

2.7 Evaluation of the Result

The calculation of flow is to be made immediately after the measurement work at the field so that the result can be checked approximately and re-measurement can be made as necessity arises.

Plot the discharge obtained on the existing H-Q curve. If the result is out of more than 10% from the H-Q curve re-calculate on the FORM. If the re-calculation gives same result, re-measurement is to be made.



Photo/illust.-19 Evaluation of the Result

2.8 Formation of a Team for Discharge Measurement

A team should be formed prior to commencement of discharge measurement and their duties are to be determined. The ordinary composition of the team and their respective in charge are as follows:

Table 2-9 Member of Team for Discharge Measurement by Current Meter

Staff	In charge
(1) Chief	- To select site for measurement, - To record staff gauge readings at initial, intermediate and end of measurement, - To check all surveyors wear life-vest properly, - To determine number of sections based on the total width measured by surveyor-2, - To call a start and an end of the measurement - To pay attention to the upstream during the measurement, to inform surveyors if a large debris/trash/drifts are flowing down to the measuring position, - To calculate discharge, - To check and confirm measurement values.
(2) Surveyor-1	- To assemble the electromagnetic current meter, sounding reel, reel board, - To measure and tell the water depth at each section to the surveyor-1, - To hang the electromagnetic current meter into the water at each section each depth.
(3) Surveyor-2	- To assemble an inflatable boat together with other surveyors, - To record the number of section and water depth told by the surveyor-1 & 3, - To tell required depth of current meter at each section to the surveyor-1, - To operate the display unit of the current meter, measure and record the

	velocity of flow.
(4) Surveyor-3 (Observer at the relevant WL station)	- To assemble an inflatable boat together with other surveyors - To expand tag line/rope on the river, - To tie the line/rope with a foot of sturdy post/tree - To measure total width of water surface and to inform it to the chief, - To grasp the line/rope and keep a boat in a proper position for each flow section in accordance with the instruction of surveyor (1) or (2) based on the determination of the chief, - To move a boat to the section where a measurement will be done, - To watch the upstream of the flow and inform to all crew if a large debris/trash/drift are flowing toward the measurement place.
(5) Surveyor-4	- To assemble an inflatable boat, - To measure total width of water surface together with surveyor-3, - To operate a boat so as to maintain the proper position during measurement and to avoid a large debris/trash/drifts, if any, which will affect the safety of the boat

In case the water depth is enough shallow for wading measurement or the measurement be made from a bridge, a boat may not be required and the duty of each surveyor will be slightly changed.

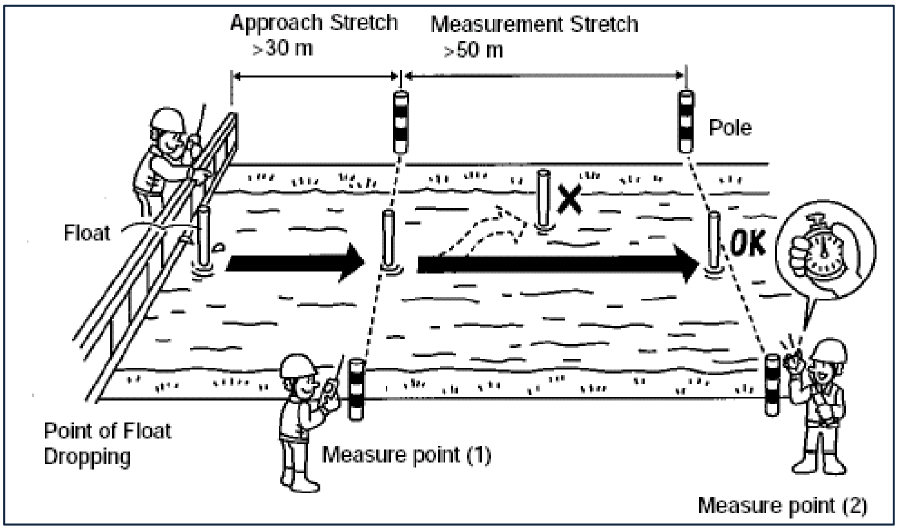
CHAPTER III

DISCHARGE MEASUREMENT BY FLOATS

3.1 Measurement Methods

The flow velocity measurement by floats is generally applied at flood measurement when a current meter could not be used.

The discharge measurement method by float is to estimate the mean flow velocity by dropping floats from upstream and by observing a time required between two sections. The river stretch of the measurement should be almost straight without meandering portions. At the measurement site, two approaches are prepared; approach stretch and measurement stretch as shown in Photo/illust.-20.



Photo/illust.-20 Measurement by Floats

The approach stretch should be more than 30 m so as to maintain float stability without vertical vibration. The measurement stretch should be more than 50 m. The number of measurement lines shall be 3 to 4 for 100m or less surface water width.

3.2 Required Equipment and Tools

The required equipment and tools for discharge measurement are floats, measuring tape, poles, transceivers/mobile phones/flags, a stopwatch and field notes.

Two types of floats i.e. surface floats and rod floats are used in general. Rod floats are usually made of wood, weighted on one end so they will float upright in the stream Rod floats are sometimes made of woods, weighted on one end so they will float upright in the stream. Rod floats are sometimes made in sections so their length can be adjusted to fit the stream depth, however care should be observed so they do not touch the streambed. Use of rod floats is desirable. However, surface floats can be also used if the rod float is not available. Surface floats may be almost anything that floats and can be distinguished easily form river bank such as wooden disks, bottles partly filled, or oranges. Floating debris may serve as natural floats.

3.3 Formation of a Team

A team should be formed prior to commencement of discharge measurement and their duties are to be determined. The ordinary composition of the team and their respective in charge are as follows:

Table 3-1 Member of Team for Discharge Measurement by Float

Staff	Duties
(1) Chief	- To manage the measurement and safety. - To determine drop and measurement lines. - To call a start and end of the measurement - To calculate the discharge - To check and confirm values measured.
(2) Surveyor (1)	- To drop of floats - To record time at drop of floats
(3) Surveyor (2)	- To send a signal when the float passes the measuring pole (1)
(4) Surveyor (3)	- To operate the stopwatch and to record the time when the float passes the measuring poles (1) and (2)
(5) Surveyor (4)	- To read water level at the staff gauge and to record the data

3.4 Procedure of Measurement by Floats

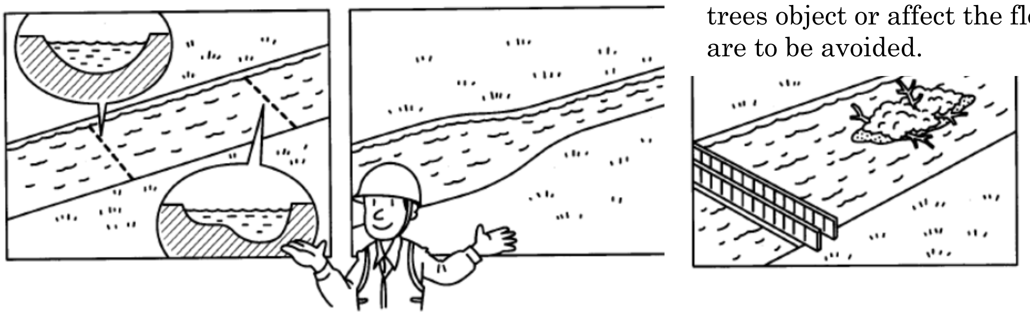
3.4.1 General

The procedure for a float measurement is to distribute a number of floats uniformly over the stream width, noting the position of each with respect to the bank. They should be placed far enough upstream from the first cross section so they attain the velocity of the stream before they reach the first cross section. A stopwatch is used to time their travel between the two cross sections. The distance of each float from the bank as it passes the second cross section should also be noted.

3.4.2 Selection of Site

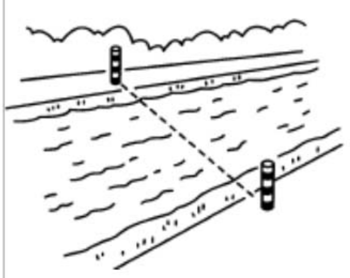
Two cross sections are selected along a reach of straight channel for a float measurement. The cross sections should be far enough apart so that the time the float takes to pass from one cross section to the other can be measured accurately. A travel-time of at least 20 seconds is recommended, but a shorter time can be used on small streams with high velocities where it is impossible to select an adequate length of straight channel.

A stretch where the cross sections and water surface appear remarkably change should not be adopted as shown in Photo/illust.-21.



Photo/illust.-21 Stretch not to be Adopted

The poles at right and left sides at the points for measurements have to be seen without any objects (Photo/illust.-21).



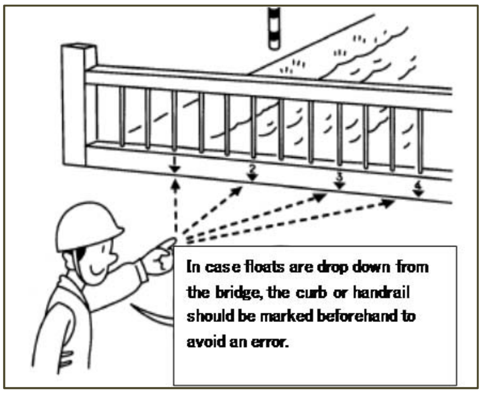
Photo/illust.-22 Poles at Measuring

The edge of water for both cross sections should be referenced to stakes (or other markers) on each bank. Those points will be used at a later date, when conditions permit, to survey cross sections of the measurement reach, and to obtain the distance between cross sections. The surveyed cross sections will be used to determine the average cross section for the reach.

3.4.3 Setting up Velocity Lines

The cross section of the river should be divided into segments by measurement lines. The measurement of velocity should be executed in each line as shown in Figure 3-4.

The standard number of velocity lines is summarized as follows:



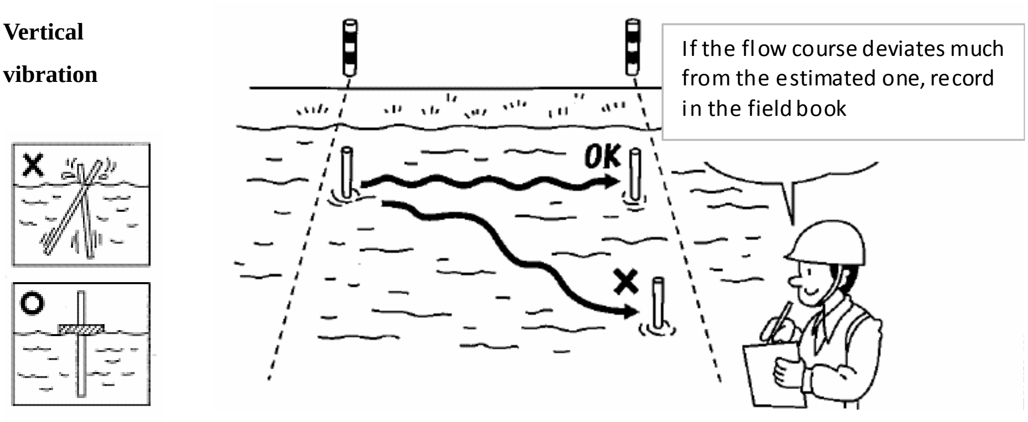
Photo/illust.-23 Setting up Velocity Lines

Table 3-2 Number of Velocity Lines by Float Measurement

Ordinary case				
Width of stream (m)	Less than 20	20 – 100	100 – 200	200 or over
Velocity line (Nos.)	5	10	15	20
Urgent case				
Width of stream (m)	Less than 50	50 – 100	100–200	200 or over
Velocity line (Nos.)	3	4	5	6 – 8

3.4.4 Check of Flow Condition

Dropping float into the river should be made gently to minimize the vertical vibration of the float. If the float flows largely deviate from the planed course as shown in Figure 3-4, the surveyor should mention the remarks in the field note. In this case, measurement shall be made repeatedly.



Photo/illust.-24 Vertical Vibration and Deviation of Flow Course

3.4.5 Flow Velocity Calculation

The velocity of the float is equal to the distance between the cross sections divided by the time of travel. The mean velocity of flow in the vertical is equal to the float velocity multiplied by a coefficient that is based on the shape of the vertical-velocity profile and relative depth of immersion of the float. A coefficient of about 0.85 is commonly used to convert surface velocity to mean velocity. The coefficient for rod floats varies from 0.85 to 1.00 depending on the shape of the cross section, the length of the rod, and the velocity distribution.

The mean flow velocity by float is calculated using the following equation:

$$V_m=\alpha \cdot L/T$$

Where,
V_m: Mean flow velocity (m/s)
L: Measurement stretch (m)
T: Flowing time for measurement stretch(s)
α: Coefficient (generally 0.8-0.95), 0.85 may be provisionally used.

3.4.6 Cross Section Survey

After a flood, a cross section survey has to be carried out at three points; staff gauge point, measurement pole point (1) and measurement pole point (2). The results of cross section survey have to be kept in the office so that the change of cross section can be compared before and after the flood.

3.4.7 Recording

The data obtained from the cross section survey and the flow velocity measurement by floats has to be recorded in a calculation sheet, to calculate the discharge. FORM-36 is available in the server computer.

The procedure for computing discharge is similar to that for a current meter measurement. The discharge in each partial section is computed by multiplying the average area of the partial section by the mean velocity in the vertical for that partial section. The total discharge is equal to the sum of the discharges for all the partial sections.

Discharge measurements made by floats under favorable conditions may be accurate to within ±10 percent. Wind may adversely affect the accuracy of the computed discharge by its effect on the velocity of the floats, especially if velocity is very slow. If a poor reach is selected and not enough float runs are made the results can be as much as 25 percent in error.

CHAPTER IV

MAKING RATING CURVES

4.1 General

Measured discharges are then plotted against concurrent water level on graph paper to define the rating curve. At a new station many discharge measurements are needed to define the water level-discharge relation throughout the entire range of water level. Periodic measurements are needed thereafter to either confirm the stability of the rating or to follow changes (shifts) in the rating. A minimum of ten discharge measurements per year is recommended, unless it has been demonstrated that the water level-discharge relation is completely unvarying with time. In that event the frequency of measurements may be reduced. It is of prime importance that the water level-discharge relation be defined for flood conditions, for extreme low flow conditions and for periods when the rating is subject to shifts as a result of the variable channel and control conditions. It is essential that the stream gauging programme provides for the non-routine measurement of discharge at those times.

If the discharge measurements cover the entire range of water level experienced during a period of time when the water level-discharge relation is stable, there is little problem in defining the discharge rating for that period. On the other hand, if, there is no discharge measurements to define the upper end of the rating the defined lower part of the rating curve must be extrapolated to the highest stage experienced. Such extrapolations are always subject to error, but the error may be minimized if the analyst has knowledge of the principles that govern the shape of rating curves.

4.2 Graphical Plotting of Water Level-Discharge

4.2.1 General

The relation between water level and discharge is defined by plotting measurements of discharge with corresponding observations of water level, taking into account whether the discharge is steady, increasing or decreasing and also noting the rate of change in water level. This may be done manually by plotting on paper or by using computerized plotting techniques. A choice of two types of plotting scale are available, either an arithmetic scale or a logarithmic scale. Each has certain advantages and disadvantages, as explained in subsequent paragraphs. It is customary to plot the water level as ordinate and the discharge as abscissa, although when using the water level-discharge relation to derive discharge from a measured value of water level, the stage is treated as the independent variable.

4.2.2 List of Discharge Measurements

The first step before making a plot of stage versus discharge is to prepare a list of discharge measurements that will be used for the plot. At a minimum this list should include at least 10 to 15 measurements, all made during the period of analysis. If the rating is segmented then more measurements may be required. These measurements should be well distributed over the range in gauge heights experienced. It should also include low and high measurements from other times that might be useful in defining the correct shape of the rating and for extrapolating the rating. Extreme low and high measurements should be included wherever possible.

For each discharge measurement in the list it is important that at least the following items are included:

(a) River and station names;

(b) Date of measurement;

(c) Gauge height of measurement. If there is a difference between start and end of measurement, list both readings;

(d) Total discharge;

4.2.3 Arithmetic Plotting Scales

The simplest type of plot uses an arithmetically divided plotting scale as shown in Figure 4-1. Scale subdivisions should be chosen to cover the complete range of gauge height and discharge expected to occur at the gauging site.

Scales should be subdivided in uniform, even increments that are easy to read and interpolate.

They should also be chosen to produce a rating curve that is not unduly steep or flat. Usually the curve anticipated should follow a slope of between 30° and 50°. If the range in gauge height or discharge is large, it may be necessary to plot the rating curve in two or more segments to provide scales that are easily read with the necessary precision. This procedure may result in separate curves for low water, medium water and high water. Care should be taken to see that, when joined, the separate curves form a smooth, continuous combined curve.

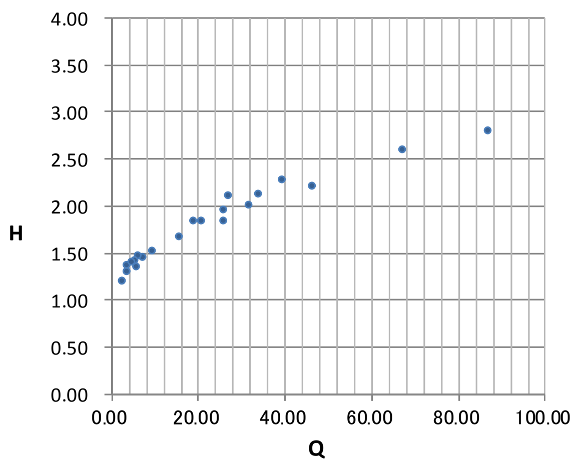


Figure 4-1 Arithmetic Plotting of Water Level-Discharge Relations

The use of arithmetic co-ordinate paper for rating analysis has certain advantages, particularly in the study of the pattern of rating shifts in the lower part of the rating. A change (shift) in the low-flow rating at many sites results from a change in the gauge height of effective zero flow, which means a constant shift in gauge height. A shift of that kind is more easily visualized on arithmetic co-ordinate paper because on that paper the shift curve is parallel to the original rating curve as shown in Figure 4-2.

The two curves are separated by a vertical distance equal to the change in the value of the gauge height of zero flow. A further advantage of arithmetic co-ordinate paper is the fact that the gauge height of zero flow can be plotted directly on arithmetic co-ordinate paper, thereby facilitating extrapolation of the low water end of the rating curve. That cannot be done on logarithmic paper because zero values cannot be shown on that type of paper.

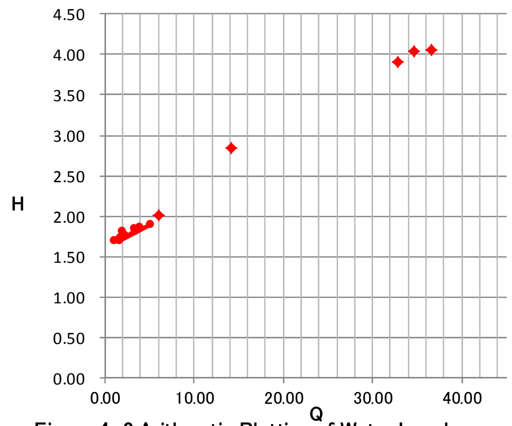


Figure 4-2 Arithmetic Plotting of Water Level-Discharge Shows a shift in Lower Part

4.2.4 Computer Plotting of Discharge Measurements

Plotting of discharge measurements and rating curves, either arithmetic plots or logarithmic plots, is best done by computer. These plots can be viewed on the computer monitor and/or plotted on paper forms. Advantages of computer plots are:

(a) Selection of measurements for plotting can be made quickly and easily;

(b) Scale changes can be made and measurements replotted quickly;

(c) Various values of e can be easily tried for the purpose of defining a straight-line rating on logarithmic plots;

(d) Separate rating segments, representing different control conditions, can be easily and quickly plotted;

(e) Rating analysis, as described in the subsequent section, is accomplished easily;

(f) Plotting errors are virtually eliminated.

It is customary to plot the square root of discharge $\sqrt{Q}$ as ordinate and, the water level as abscissa due to the reasons described in the following section.

4.2.5 Making an Approximate Curve

A linear equation can be obtained by computer plotting and function above described as follows:

$$\sqrt{Q} = \alpha H - \beta \qquad (4.1)$$

Where, *Q*=discharge, α= a slope of the straight line drawn in the above section, *H*= water level, β = an intercept

The H-Q curve is commonly presented by a quadratic curve of equation of (4.1) as follows:

$$Q = a(H - b)^2 \qquad (4.2)$$

Where; a=α^2, b=$\frac{\beta}{\alpha}$ in the above linear equation.

Two representative samples are presented in Figures 3-3 and 3-4.

The FORM-41 and FORM-42 are made available for making a single H-Q curve and a two H-Q curve respectively in the server computer

Station:		Dong Tung			
No.	Year	Month	Date	Measured Q	H
				(m^3/s)	(m)
1	2006	12	13	7.09	1.46
2	2007	1	3	5.51	1.36
3	2007	1	23	3.56	1.30
4	2007	2	20	2.15	1.21
5	2007	3	7	2.16	1.21
6	2007	6	29	39.10	2.28
7	2007	7	12	33.71	2.14
8	2007	7	24	26.65	2.11
9	2007	8	9	25.85	1.84
10	2007	8	24	46.13	2.21
11	2007	9	9	18.67	1.85
12	2007	9	16	25.79	1.96
13	2007	9	25	20.45	1.84
14	2007	10	4	86.51	2.80
15	2007	10	23	31.65	2.02
16	2007	11	4	15.61	1.68
17	2007	11	19	67.11	2.61
18	2007	12	7	9.18	1.53
19	2007	12	19	5.96	1.48
20	2008	1	8	5.13	1.42
21	2008	1	26	3.21	1.38
22	2008	2	5	4.37	1.41

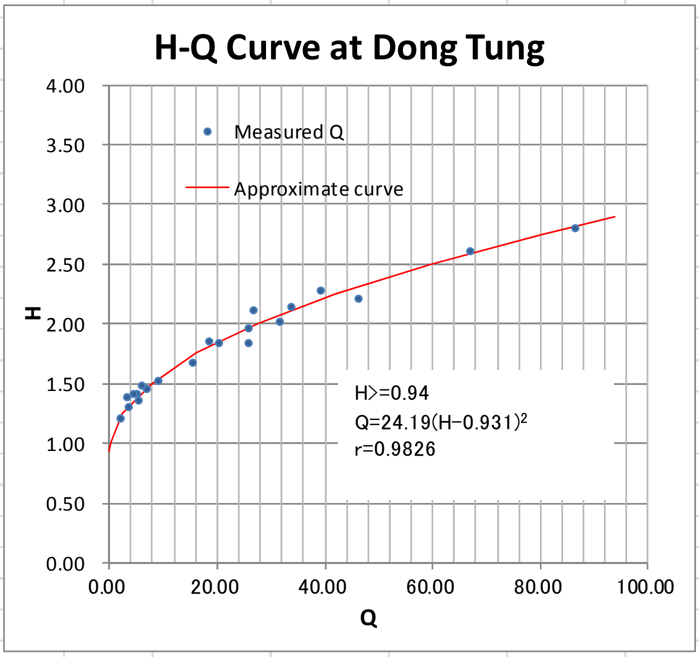


Figure 4-3 Single H-Q Curve

d. Moung Russey Rating Curve

	Station			Moung Russey	
No.	Year	Date		Measurd Q	H
				(m3/s)	(m)
1	2007	Jul	2	6.02	2.01
2	2007	Jul	12	3.46	1.82
3	2007	Jul	25	5.16	1.89
4	2007	Aug	10	1.60	1.69
5	2007	Aug	25	3.88	1.87
6	2007	Sep	9	3.28	1.85
7	2007	Sep	17	32.78	3.90
8	2007	Sep	26	2.32	1.76
9	2007	Oct	5	2.06	1.74
10	2007	Oct	24	36.66	4.05
11	2007	Nov	5	14.09	2.84
12	2007	Nov	20	34.66	4.04
13	2007	Dec	8	2.03	1.82
14	2007	Dec	20	1.07	1.70
15	2008	Jan	9	0.00	1.70
16	2008	Jan	26	0.00	1.60
17	2008	Feb	9	0.00	1.62

Not used

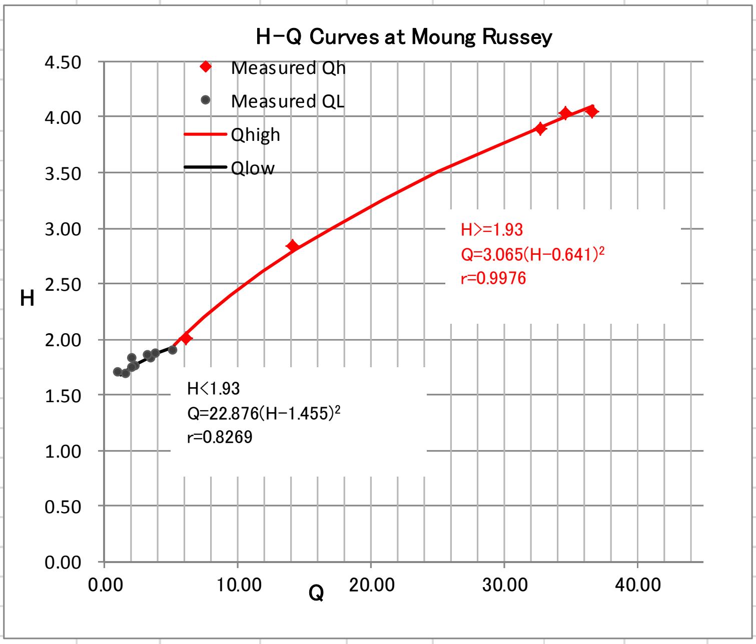


Figure 4-4 Two H-Q Curves for Low and High Water Levels

CHAPTER V

CALCULATION OF DISCHARGE BY H-Q CURVES

5.1 General

Applying water level records to the H-Q curve(s) the discharge of the river can be obtained.

The project has two types of water level stations i.e. automatic water level (AWL) station and staff gauge (STG) station. The kind of record is different as follows:

Table 5-1 Kind of Water Level Records

Type of water level stations	Means of measurements	Interval of measurements
Automatic water level station	By a transducer/bubble/radar sensor	every 15 minutes
	Reading staff gauge(s) by an observer	Two times in a day (7 am & 7 pm)
Staff gauge station	Reading staff gauge(s) by an observer	Two times in a day (7 am & 7 pm)

The water level records at AWL station have to be finalized as discussed in the Manual on Rainfall and Water Level Observation before those are applied to the H-Q curve(s).

5.2 Calculation of Daily Mean Discharge by H-Q Curves

A sample calculation sheet is made as shown in Table 5-2. A spread sheet in MSExcel format is attached in this manual.

Table 5-2 Calculation of Discharge by H-Q Curves

	Discharge Measurement FORM-41		
Calculation of Discharge by Applying H-Q Curves			
River:	Moung Russei	Station:	Moung Russei
Coordinate: E		N	
Month:	August	Year:	2015
H-Q curve: Q=a(H+b)^2			
H-Q Curve #1		H-Q Curve #2	
H<	**1.93**	H>=	**1.93**
a_1=	b_1=	a_2=	b_2=
22.876	**-1.455**	**3.065**	**-0.641**
Calculation			
Date (yyyy/mm/dd)	**Time**	**H (WL)**	**Q**
2015/8/5	0:15	1.95	5.252
2015/8/5	0:30	2.05	6.085
2015/8/5	0:45	2.07	6.259
2015/8/5	1:00	2.07	6.259
2015/8/5	1:15	2.06	6.172
	■		
	■		
	■		
	■		
2015/8/5	23:30	1.69	1.263
2015/8/5	23:45	1.68	1.158
2015/8/5	0:00	1.67	1.057
Average		**1.86**	**3.713**
Max.		**2.07**	**6.259**
Min.		**1.67**	**1.057**
Total Q in million m3		**-**	**0.321**

The important values can be seen from the above table as follows:

Table 5-3 Important Daily Values

Description	Unit	Value	Remarks
Daily mean water level	m	1.86	The definition of daily mean water level is the arithmetic mean of all water levels in the relevant day
Daily maximum water level	m	2.07	The definition of daily maximum water level is the maximum value of all water levels in the relevant day
Daily minimum water level	m	1.67	The definition of daily minimum water level is the minimum value of all water levels in the relevant day
Daily mean discharge	m^3/sec	3.713	The definition is the arithmetic mean of all discharge data calculated by applying H-Q curve.
Daily maximum discharge	m^3/sec	6.259	The definition is the maximum value of all discharge data calculated by applying H-Q curve.
Daily minimum discharge	m^3/sec	1.057	The definition is the minimum value of all discharge data calculated by applying H-Q curve.
Total volume of discharge	Million m^3	0.321	The definition is the total amount of discharge passed at the gauging station in a relevant day

5.3 Calculation of Monthly and Annual Values

5.3.1 General

Monthly and annual values of water level and discharge should be computed for each station as required or designated. All computations of monthly values should be based on the rounded results of daily values and all computations of annual values should be based on rounded results of either daily or monthly values, as indicated. Therefore, consistent agreement will be made the daily, monthly and annual values.

At least two sets of annual values should be computed for each gauging station: (a) for the calendar year, January through December and (b) for the water year, October through September. In special cases the surveyor may designate additional or alternative types of years, such as the climatic year, April through March.

5.3.2 Monthly and Annual Values of Discharge

Monthly and annual values of discharge should be computed for gauging stations where daily discharge is routinely computed and where streamflow is the parameter of primary interest. Some of the monthly and annual values are required, whereas others are optional, and are computed only for specific gauging stations. The optional computations generally are designated on the basis of streamflow conditions, drainage basin size, natural runoff conditions, degree of regulation and other factors that may affect the hydrologic value and need for the computed parameters.

The monthly discharge values that are required are the following:

(a) Monthly total discharge – Total of all daily mean discharges for each month;

(b) Monthly mean discharge – The mean of all daily mean discharges for each month, and is computed by dividing the monthly total discharge by the number of days in the month i.e. 31, 30, or 28, 29 for February in leap year;

(c) Monthly minimum daily discharge – The lowest daily mean discharge for each month;

(d) Monthly maximum daily discharge – The highest daily mean discharge for each month.

The annual discharge values that are required are as follows:

(a) Annual total discharge – The total of all daily mean discharges for the year;

(b) Annual mean discharge – The mean of all daily mean discharges for the year, and is computed by dividing the annual total discharge by 365 or by 366 for leap years;

(c) Annual minimum daily discharge – The lowest daily mean discharge for the year;

(d) Annual maximum daily discharge – The highest daily mean discharge for the year.

A sample sheet is presented in Table 5-4. A spread sheet in MSExcel format is attached in this manual.

Table 5-4 Calculation of Monthly and Annual Values

				Discharge Measurement FORM-42								
				Daily mean, Monthly Mean and Annual Mean Discharges								
River:				Station:							E:	
Year:				District:							N:	
Input by:				Province:							Alt.(amsl):	
												(Unit: m3/sec)
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	9.46	5.63	12.03	6.99	27.67	24.08	19.61	12.93	11.45	8.91	16.66	17.63
2	9.46	5.63	8.15	7.22	27.67	37.85	19.94	12.63	11.16	8.63	16.02	19.61
3	9.18	5.41	7.57	10.30	28.40	51.63	18.77	12.33	10.58	8.15	14.76	28.04
4	8.91	5.41	6.99	12.03	25.14	50.34	17.79	12.33	10.30	7.91	12.63	33.29
			■									
			■									
			■									
			■									
			■									
27	5.85	6.19	6.99	39.77	38.37	21.64	14.76	12.63	9.18	21.64	19.94	16.66
28	5.63	6.53	6.76	34.45	37.39	21.64	14.45	12.33	9.18	18.61	18.28	15.70
29	5.63	12.42	7.45	28.40	41.02	22.33	14.14	12.03	9.18	18.94	18.61	14.76
30	5.63		7.22	26.94	45.09	20.62	14.14	11.74	9.18	19.27	18.61	15.70
31	5.63		7.10		48.36		13.53	11.74		17.63		16.98
Total	**228.97**	**171.08**	**252.80**	**497.13**	**1058.99**	**976.09**	**515.72**	**377.68**	**285.76**	**298.37**	**445.75**	**674.04**
No. of day	31	28	31	30	31	30	31	31	30	31	30	31
Average	**7.39**	**6.11**	**8.15**	**16.57**	**34.16**	**32.54**	**16.64**	**12.18**	**9.53**	**9.62**	**14.86**	**21.74**
Max.	**9.46**	**12.42**	**13.23**	**44.87**	**48.64**	**51.63**	**27.97**	**13.53**	**11.45**	**21.64**	**30.26**	**33.29**
Min.	**5.63**	**4.32**	**5.85**	**6.99**	**23.37**	**20.62**	**13.53**	**10.30**	**9.18**	**6.76**	**10.01**	**14.14**
Annual total discharge:					**5,782.37**	m3/sec	**Annual max. discharge:**			**51.63**	**m3/sec**	
Annual mean discharge:					**15.84**	m3/sec	**Annual min. discharge:**			**4.32**	**m3/sec**	

FORMS

Discharge Measurement FORM-33

Two-tenth (0.2D) Method (0.6 m<D≦3 m, $v_m=0.87v_{0.2D}$)

Station: Date: 2007/7/2 Time: 2.47pm to 3.50pm WL: 2.01 to 2.01

No.	Cumulative distance of vertical line (m)	Remark ex. end of water surface, column of bridge, island, etc.	Angle between flow and tag line, A (°)	Angle between vertical line and current meter, B (°)	Water depth (m)		Measure. point from water surface (m)						Flow Velocity (m/sec)								Vave adjusted by cos(A) (m)
							0.2D						0.2D						Vave (m/s)	cos(A)	
					1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time	2nd time			
R or L																					
0	0.00	Edge of water	0.0	0.0	0.00	0.00							0.000						0.000	1.000	0.000
1	2.00		0.0	0.0	1.20	1.20	0.24	0.24					0.140	0.120					0.113	1.000	0.113
2	4.00		0.0	0.0	1.26	1.24	0.25	0.248					0.220	0.230					0.196	1.000	0.196
3	6.00		0.0	0.0	2.20	2.19	0.44	0.44					0.310	0.290					0.261	1.000	0.261
4	8.00		0.0	0.0	2.19	2.19	0.44	0.44					0.340	0.340					0.296	1.000	0.296
5	10.00		0.0	0.0	2.00	2.00	0.40	0.40					0.340	0.340					0.296	1.000	0.296
6	12.00		0.0	0.0	1.74	1.75	0.35	0.35					0.300	0.300					0.261	1.000	0.261
7	14.00		0.0	0.0	1.37	1.37	0.27	0.27					0.180	0.150					0.144	1.000	0.144
8	16.00		0.0	0.0	0.64	0.65	0.13	0.13					0.060	0.050					0.048	1.000	0.048
9	18.00	Edge of water			0.00	0.00	0.00	0.00												1.000	
10																				1.000	
11																				1.000	
12																				1.000	
13																				1.000	
14																				1.000	
R or L																				1.000	
Total or average					1.26	1.26							0.21	0.23	######	######	######	######	0.179		0.179
Observer:		Calculater:								Note:											

Discharge Measurement FORM-33

Station: 0 **Date:** 2007/7/2

No.	Cumulative distance of vertical line (m)	1st measurement: Angle B & Table 2-2 for air adjust.	1st measurement: Air adjusted	1st measurement: Angle B & Table 2-3 for wet line adjust,	1st measurement: Wet line adjusted	2nd measurement: Angle B & Table 2-2 for air adjust.	2nd measurement: Air adjusted	2nd measurement: Angle B & Table 2-3 for wet line adjust,	2nd measurement: Wet line adjusted	Dave., depth at velocity line (m)	Distance: W (m)	Distance: 0.5W (m)	Section area: Depth for calcu. (m)	Section area: ⊿S (m2)	Section area: S (m2)	Q (m3/s)
R or L																
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		1.00	0.000	0.300	0.300	0.000
											2.00	1.00	0.600	0.900		
1	2.00	0.00	1.20	0.00	1.20	0.00	1.20	0.00	1.20	1.20		1.00	1.200	1.213	2.113	0.239
											2.00	1.00	1.225	1.238		
2	4.00	0.00	1.26	0.00	1.26	0.00	1.24	0.00	1.24	1.25		1.00	1.250	1.486	2.724	0.533
											2.00	1.00	1.723	1.959		
3	6.00	0.00	2.20	0.00	2.20	0.00	2.19	0.00	2.19	2.20		1.00	2.195	2.194	4.153	1.084
											2.00	1.00	2.193	2.191		
4	8.00	0.00	2.19	0.00	2.19	0.00	2.19	0.00	2.19	2.19		1.00	2.190	2.143	4.334	1.282
											2.00	1.00	2.095	2.048		
5	10.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	2.00		1.00	2.000	1.936	3.984	1.178
											2.00	1.00	1.873	1.809		
6	12.00	0.00	1.74	0.00	1.74	0.00	1.75	0.00	1.75	1.75		1.00	1.745	1.651	3.460	0.903
											2.00	1.00	1.558	1.464		
7	14.00	0.00	1.37	0.00	1.37	0.00	1.37	0.00	1.37	1.37		1.00	1.370	1.189	2.653	0.381
											2.00	1.00	1.008	0.826		
8	16.00	0.00	0.64	0.00	0.64	0.00	0.65	0.00	0.65	0.65		1.00	0.645	0.484	1.310	0.063
											2.00	1.00	0.323	0.161		
9	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.000	0.000	0.161	0.000
												0.00	0.000	0.000		
10												0.00		0.000	0.000	0.000
												0.00		0.000		
11												0.00		0.000	0.000	0.000
												0.00		0.000		
12												0.00		0.000	0.000	0.000
												0.00		0.000		
13												0.00		0.000	0.000	0.000
												0.00		0.000		
14												0.00		0.000	0.000	0.000
												0.00		0.000		
R or L												0.00			0.000	0.000
Total or average		0.00	1.26	0.00	1.26	0.00	1.26	0.00	1.26	1.26	18.00	18.00	1.260	25.190	25.190	5.663
Observer:																

Discharge Measurement FORM-34

1-point (0.3m<D<=0.6m, $v_m=v_{0.6D}$), 2-point (0.6m<D≦3m, $v_m=(v_{0.2D}+v_{0.8D})/2$) and/or 3-point (3.0m<D≦6.0m, $v_m=((v_{0.2D}+2\times v_{0.6D}+v_{0.8D})/4)$ Methods

Station: Bak Trakoun **Date:** 2015/9/9 **Time:** 15:37 **to** 17:20 **WL:** 0.87 **to** 0.90

No.	Cumulative distance of vertical line (m)	Remark ex. end of water surface, column of bridge, island, etc.	Angle between flow and tag line, A (°)	Angle between vertical line and current meter, B (°)	Water depth (m) 1st time	Water depth (m) 2nd time	Measure. point from water surface (m) 0.2D 1st time	0.2D 2nd time	0.6D 1st time	0.6D 2nd time	0.8D 1st time	0.8D 2nd time	Flow Velocity (m/sec) 0.2D 1st time	0.2D 2nd time	0.6D 1st time	0.6D 2nd time	0.8D 1st time	0.8D 2nd time	Vave (m/s)	cos(A)	Vave adjusted by cos(A) (m)
R or L																					
0	8.80	Edge of wate	0.0		0.00															1.000	0.000
1	10.50		0.0		0.51				0.306						0.278				0.278	1.000	0.278
2	12.00		0.0		0.96		0.19				0.77		0.276				0.261		0.269	1.000	0.269
3	18.00		0.0		1.30		0.28				1.04		0.306				0.217		0.262	1.000	0.262
4	22.14	Edge of wate	0.0		1.01		0.20				0.80		0.024				0.000		0.012	1.000	0.012
		Footing of column																			
5	24.88	Edge of water			1.44		0.29				1.15		0.000				0.303		0.152	1.000	0.152
6	33.00		0.0		3.01		0.60				2.41		0.535				0.367		0.451	1.000	0.451
7	40.50		0.0		2.50		0.50				2.00		0.384				0.335		0.360	1.000	0.360
8	46.00	Edge of water			1.62		0.32				1.30		0.035				0.282		0.159	1.000	0.159
		Footing of column																			
9	49.00	Edge of water			1.63		0.33				1.30		0.000				0.232		0.116	1.000	0.116
10	55.00		0.0		1.19		0.24				0.95		0.000				0.000		0.000	1.000	0.000
11	70.00	Edge of water			0.61				0.37						0.000				0.000	1.000	0.000
		Footing of column																			
12	72.70	Edge of water			0.61				0.37						0.000				0.000	1.000	0.000
13	79.40	Edge of wate	0.0		0.00																
14																					
R or L																					
Total or average					1.17	######							0.17	######	0.09	######	0.22	######	0.171		0.158

Observer: Calculater: Note:

Discharge Measurement FORM-34

Station: Bak Trakoun **Date:** 2015/9/9

No.	Cumulative distance of vertical line (m)	Adjustment of water depth by the angle between vertical line and current meter: 1st measurement: Angle B & Table 2-2 for air adjust.	Air adjusted	Angle B & Table 2-3 for wet line adjust,	Wet line adjusted	2nd measurement: Angle B & Table 2-2 for air adjust.	Air adjusted	Angle B & Table 2-3 for wet line adjust,	Wet line adjusted	Dave., depth at velocity line (m)	Distance: W (m)	0.5W (m)	Section area: Depth for calcu. (m)	⊿S (m2)	S (m2)	Q (m3/s)
R or L																
0	8.80		0.00		0.00					0.00		0.85	0.000	0.108	0.108	0.000
											1.70	0.85	0.255	0.325		
1	10.50		0.51		0.51					0.51		0.75	0.510	0.467	0.792	0.220
											1.50	0.75	0.735	0.636		
2	12.00		0.96		0.96					0.96		3.00	0.960	3.135	3.771	1.012
											6.00	3.00	1.130	3.645		
3	18.00		1.30		1.30					1.30		2.07	1.300	2.541	6.186	1.618
											4.14	2.07	1.155	2.241		
4	22.14		1.01		1.01					1.01		0.00	1.010	0.000	2.241	0.027
												0.00	1.225	0.000		
5	24.88		1.44		1.44					1.44		4.06	1.440	7.440	7.440	1.127
											8.12	4.06	2.225	10.627		
6	33.00		3.01		3.01					3.01		3.75	3.010	10.809	21.436	9.668
											7.50	3.75	2.755	9.853		
7	40.50		2.50		2.50					2.50		2.75	2.500	6.270	16.123	5.796
											5.50	2.75	2.060	5.060		
8	46.00		1.62		1.62					1.62		0.00	1.620	0.000	5.060	0.802
												0.00	1.625	0.000		
9	49.00		1.63		1.63					1.63		3.00	1.630	4.560	4.560	0.529
											6.00	3.00	1.410	3.900		
10	55.00		1.19		1.19					1.19		7.50	1.190	7.838	11.738	0.000
											15.00	7.50	0.900	5.663		
11	70.00		0.61		0.61					0.61		0.00	0.610	0.000	5.663	0.000
												0.00	0.610	0.000		
12	72.70		0.61		0.61					0.61		3.35	0.610	1.533	1.533	0.000
											6.70	3.35	0.305	0.511		
13	79.40		0.00		0.00					0.00		0.00	0.000	0.000	0.511	0.000
												0.00	0.000	0.000		
14												0.00		0.000	0.000	0.000
												0.00		0.000		
R or L												0.00			0.000	0.000
Total or average		#DIV/0!	1.17	#DIV/0!	1.17	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.17	62.16	62.16	1.171	87.161	87.161	20.799

Observer:

Discharge Measurem surement FORM-35

5-point (6.0m<D, $v_m=0.1(v_{surface}+3v_{0.2D}+3v_{0.6D}+2v_{08D}+v_{bed})$) incl. 1-point (0.3m<D<=0.6m, $v_m=v_{0.6D}$), 2-point 2-point (0.6m<D≦3m, $v_m=(v_{0.2D}+v_{0.8D})/2$), 3-point (3.0m<D≦6.0m, $v_m=((v_{0.2D}+2\times v_{0.6D}+v_{0.8D})/4)$ M

Station: **Date:** 2007/7/2 **Time:** 2.47pm **to** 3.50pn pm **WL:** 2.01 **to** 2.01

No.	Cumulative distance of vertical line (m)	Remark ex. end of water surface, column of bridge, island, etc.	Angle between flow and tag line, A (°)	Angle between vertical line and current meter, B (°)	Water depth (m)		Measure. point from water surface (m)										Flow Velocity (m/sec)									
							0.3m from surface		0.2D		0.6D		0.8D		0.3m from bottom		surface		0.2D		0.6D		0.8D		0.3m fror
					1st time	2nd time	1st	2nd	1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time	2nd time	1st time
R or L																									
0	0.00	Edge of wat	0.0	0.0	0.00	0.00					0.00		0.00									0.000			
1	6.00		0.0	0.0	0.50	0.54					0.30	0.32									0.400	0.420			
2	12.00		0.0	0.0	1.30	1.34			0.26	0.27			1.04	1.07					0.420	0.435			0.360	0.340	
3	18.00		0.0	0.0	2.50	2.44			0.50	0.49			2.00	1.95					0.752	0.760			0.600	0.560	
4	24.00		0.0	0.0	4.60	4.50			0.92	0.90	2.76	2.70	3.68	3.60					1.050	1.060	1.350	0.340	0.900	0.980	
5	30.00		0.0	0.0	6.80	6.86	0.30	0.30	1.36	1.37	4.08	4.12	5.44	5.49	6.50	6.56	0.600	0.630	1.360	1.340	1.450	1.440	1.000	1.080	0.800
6	36.00		0.0	0.0	6.20	6.14	0.30	0.30	1.24	1.23	3.72	3.68	4.96	4.91	5.90	5.84	0.610	0.610	1.380	1.350	1.460	1.470	0.900	0.980	0.760
7	42.00		0.0	0.0	5.00	5.02			1.00	1.00	3.00	3.01	4.00	4.02					1.120	1.130	1.520	1.540	0.930	0.940	
8	48.00		0.0	0.0	3.30	3.34			0.66	0.67	1.98	2.00	2.64	2.67					0.980	0.970	1.250	1.260	0.800	0.840	
9	54.00				1.40	1.44			0.28	0.29			1.12	1.15					0.710	0.750			0.600	0.560	
10	58.00	Edge of water			0.00	0.00					0.00										0.000	0.000			
11																									
12																									
13																									
14																									
R or L																									
Total or average					2.87	2.87											0.61	0.62	0.97	0.97	1.06	0.81	0.761	0.785	0.78

Observer: Calculater: Note:

Discharge Measurement FORM-35

5-point (6.0rethods

Station: 0 **Date:** 2007/7/2

No.	Cumulative distance of vertical line (m)	n bottom 2nd time	Vave (m/s)	cos(A)	Vave adjusted by cos(A) (m)	Adjustment of water depth by the angle between vertical line and current meter: 1st measurement: Angle B & Table 2-2 for air adjust.	1st measurement: Air adjusted	1st measurement: Angle B & Table 2-3 for wet line adjust,	1st measurement: Wet line adjusted	2nd measurement: Angle B & Table 2-2 for air adjust.	2nd measurement: Air adjusted	2nd measurement: Angle B & Table 2-3 for wet line adjust,	2nd measurement: Wet line adjusted	Dave., depth at velocity line (m)	Distance: W (m)	Distance: 0.5W (m)	Section area: Depth for calcu. (m)	Section area: ⊿S (m2)	Section area: S (m2)	Q (m3/s)
R or L																				
0	0.00		0.000	1.000	0.000		0.00		0.00		0.00		0.00	0.00		3.00	0.000	0.390	0.390	0.000
															6.00	3.00	0.260	1.170		
1	6.00		0.410	1.000	0.410		0.50		0.50		0.54		0.54	0.52		3.00	0.520	2.160	3.330	1.365
															6.00	3.00	0.920	3.360		
2	12.00		0.389	1.000	0.389		1.30		1.30		1.34		1.34	1.32		3.00	1.320	4.823	8.183	3.181
															6.00	3.00	1.895	6.548		
3	18.00		0.668	1.000	0.668		2.50		2.50		2.44		2.44	2.47		3.00	2.470	8.970	15.518	10.366
															6.00	3.00	3.510	12.090		
4	24.00		0.921	1.000	0.921		4.60		4.60		4.50		4.50	4.55		3.00	4.550	15.360	27.450	25.288
															6.00	3.00	5.690	18.780		
5	30.00	0.840	1.190	1.000	1.190		6.80		6.80		6.86		6.86	6.83		3.00	6.830	19.995	38.775	46.142
															6.00	3.00	6.500	19.005		
6	36.00	0.740	1.173	1.000	1.173		6.20		6.20		6.14		6.14	6.17		3.00	6.170	17.640	36.645	42.985
															6.00	3.00	5.590	15.900		
7	42.00		1.280	1.000	1.280		5.00		5.00		5.02		5.02	5.01		3.00	5.010	13.763	29.663	37.968
															6.00	3.00	4.165	11.228		
8	48.00		1.076	1.000	1.076		3.30		3.30		3.34		3.34	3.32		3.00	3.320	8.535	19.763	21.269
															6.00	3.00	2.370	5.685		
9	54.00		0.655	1.000	0.655		1.40		1.40		1.44		1.44	1.42		2.00	1.420	2.130	7.815	5.119
															4.00	2.00	0.710	0.710		
10	58.00		0.000	1.000	0.000		0.00		0.00		0.00		0.00	0.00		0.00	0.000	0.000	0.710	0.000
																0.00		0.000		
11				1.000												0.00		0.000	0.000	0.000
																0.00		0.000		
12				1.000												0.00		0.000	0.000	0.000
																0.00		0.000		
13				1.000												0.00		0.000	0.000	0.000
																0.00		0.000		
14				1.000												0.00		0.000	0.000	0.000
																0.00		0.000		
R or L																0.00			0.000	0.000
Total or average		0.79	0.706		0.706	#DIV/0!	2.87	#DIV/0!	2.87	#DIV/0!	2.87	#DIV/0!	2.87	2.87	58.00	58.00	3.010	188.240	188.240	193.683
Observer:																				

Discharge Measurement, FORM-36

(For Float Method in Flood Time)

Date:	2007/6/1	Station name:		Observer:		Calculater:	
Start time:	10:10	WL (start):	8.12 m	Checker:			
End time:	12:20	WL (end):	8.10 m	Distance between MP(u/s) and MP(d/s) L	50 m		

Measurement Point: Upstream (MPu/s)

	Distance (m)	W (m)	⊿W (m)	D1 (m)	D2 (m)	Dave (m)	D− (m)	⊿S (m2)	S (m2)
R/L	0.0		10.0	0.00		0.00	0.00	6.3	6.3
		20.0	10.0				1.25	18.8	
1	20.0		7.5	2.40	2.60	2.50	2.50	20.1	38.8
		15.0	7.5				2.85	22.7	
2	35.0		7.5	3.20	3.20	3.20	3.20	27.1	49.8
		15.0	7.5				4.03	33.3	
3	50.0		7.5	4.80	4.90	4.85	4.85	34.8	68.1
		15.0	7.5				4.43	31.6	
4	65.0		7.5	4.00	4.00	4.00	4.00	22.5	54.1
		15.0	7.5	0.00			2.00	7.5	
5	80.0					0.00		0.0	7.5
6									
7									

Measurement Point: Downstream (MPd/s)

	Distance (m)	W (m)	⊿W (m)	D1 (m)	D2 (m)	Dave (m)	Dv (m)	⊿S (m2)	S (m2)
R/L	0.0		7.5	0.00		0.00	0.00	4.5	4.5
		15.0	7.5				1.20	13.5	
1	15.0		25.0	2.40	2.40	2.40	2.40	67.2	80.7
		15.0	7.5				2.98	24.5	
2	30.0		7.5	3.60	3.50	3.55	3.55	29.3	53.8
		20.0	10.0				4.28	46.4	
3	50.0		0.0	5.10	4.90	5.00	5.00	0.0	46.4
		50.0	25.0				2.70	71.3	
4	65.0		7.5	3.05	2.95	3.00	3.00	16.9	88.1
		15.0	7.5	0.00			1.50	5.6	
5	80.0					0.00		0.0	5.6
6									
7									

Calculation of Velocity and Disharge

MLd	S average (m2)	Float type (m)	Time MP(u/s) (hr : min : sec)	Time MP(d/s) (hr : min : sec)	Duration (sec)	V =L/Time (m/s)	Qo = V x S (m3/s)	Q = α x Q (m3/s)
R/L	5.4		−	−	−	−	0.0	0.0
1	59.8		10:12:00	10:13:20	80	0.63	37.34	31.7
2	51.8		10:30:00	10:30:35	35	1.43	74.00	62.9
3	57.2		10:59:50	11:00:12	22	2.27	130.04	110.5
4	71.1		11:20:00	11:20:33	33	1.52	107.74	91.6
5	6.6		−	−	−	−	0.0	0.0
6								
7								
	251.8					1.18		296.8

Remarks:

α = 0.85

FORM-37 Discharge Measurement Note

Code of station:

Name of station: Name of river:

Date (yyyy/mm/dd):

Member of measurement:

Type of measurement; (1) Current meter AEM1-D, (2) Float, (3)

Method: (1) Wading, (2) Bridge, (3) Boat,

Time of measurement: Start at hr. min. - Finish at hr. min.

G.H. at start: m G.H. at the enc m

Width of water surface in meter: m

Number of verticals:

Method of velocity measur.: (1) 1-point, (2) 2-point, (3) 3-point, (4) Other method

Vertical angle (for air correction): ° Coeff.:

Vertical angle (for wet-line correction): ° Coeff.:

Horizontal angle: ' cos α :

Total discharge: m^3/sec

Total water area: m^2

Average velocity: m/sec

Weather:

Flow: (1) Slow, (2) Rapid but smooth, (3) Rapid with turbulance

Water level at recorder at start: m Date of check the recorder

Water level at recorder at finish: m

Checked by:

Date:

Remarks:

Discharge Measurement FORM-41

Calculation of Discharge by Applying H-Q Curves

River:	Moung Russei	Station:	Moung Russei
Coordinate: E		N	
Month:	August	Year:	2015

H-Q curve: $Q=a(H+b)^2$

H-Q Curve #1		H-Q Curve #2	
H< **1.93**		H>= **1.93**	
a_1=	b_1=	a_2=	b_2=
22.876	**-1.455**	**3.065**	**-0.641**

Calculation

Date (yyyy/mm/dd)	Time	H	Q
2015/8/5	0:15	1.95	5.252
2015/8/5	0:30	2.05	6.085
2015/8/5	0:45	2.07	6.259
2015/8/5	1:00	2.07	6.259
2015/8/5	1:15	2.06	6.172
2015/8/5	1:30	2.06	6.172
2015/8/5	1:45	2.05	6.085
2015/8/5	2:00	2.05	6.085
2015/8/5	2:15	2.04	5.999
2015/8/5	2:30	2.03	5.913
2015/8/5	2:45	2.03	5.913
2015/8/5	3:00	2.03	5.913
2015/8/5	3:15	2.03	5.913
2015/8/5	3:30	2.02	5.829
2015/8/5	3:45	2.02	5.829
2015/8/5	4:00	2.01	5.744
2015/8/5	4:15	2.01	5.744
2015/8/5	4:30	2.00	5.661
2015/8/5	4:45	2.00	5.661
2015/8/5	5:00	2.00	5.661
2015/8/5	5:15	1.98	5.495
2015/8/5	5:30	1.97	5.414
2015/8/5	5:45	1.96	5.332
2015/8/5	6:00	1.95	5.252
2015/8/5	6:15	1.95	5.252
2015/8/5	6:30	1.94	5.172
2015/8/5	6:45	1.93	5.093
2015/8/5	7:00	1.93	5.093
2015/8/5	7:15	1.92	4.946
2015/8/5	7:30	1.93	5.093
2015/8/5	7:45	1.92	4.946
2015/8/5	8:00	1.93	5.093
2015/8/5	8:15	1.92	4.946
2015/8/5	8:30	1.93	5.093
2015/8/5	8:45	1.92	4.946
2015/8/5	9:00	1.92	4.946
2015/8/5	9:15	1.91	4.736
2015/8/5	9:30	1.91	4.736
2015/8/5	9:45	1.90	4.530
2015/8/5	10:00	1.90	4.530
2015/8/5	10:15	1.90	4.530
2015/8/5	10:30	1.88	4.132
2015/8/5	10:45	1.88	4.132
2015/8/5	11:00	1.87	3.940
2015/8/5	11:15	1.86	3.752
2015/8/5	11:30	1.86	3.752
2015/8/5	11:45	1.86	3.752

2015/8/5	12:00	1.85	3.569
2015/8/5	12:15	1.85	3.569
2015/8/5	12:30	1.85	3.569
2015/8/5	12:45	1.84	3.391
2015/8/5	13:00	1.83	3.217
2015/8/5	13:15	1.83	3.217
2015/8/5	13:30	1.82	3.048
2015/8/5	13:45	1.82	3.048
2015/8/5	14:00	1.82	3.048
2015/8/5	14:15	1.82	3.048
2015/8/5	14:30	1.81	2.883
2015/8/5	14:45	1.81	2.883
2015/8/5	15:00	1.80	2.723
2015/8/5	15:15	1.81	2.883
2015/8/5	15:30	1.81	2.883
2015/8/5	15:45	1.80	2.723
2015/8/5	16:00	1.81	2.883
2015/8/5	16:15	1.80	2.723
2015/8/5	16:30	1.80	2.723
2015/8/5	16:45	1.80	2.723
2015/8/5	17:00	1.80	2.723
2015/8/5	17:15	1.78	2.416
2015/8/5	17:30	1.77	2.270
2015/8/5	17:45	1.76	2.128
2015/8/5	18:00	1.75	1.991
2015/8/5	18:15	1.75	1.991
2015/8/5	18:30	1.74	1.858
2015/8/5	18:45	1.74	1.858
2015/8/5	19:00	1.73	1.730
2015/8/5	19:15	1.73	1.730
2015/8/5	19:30	1.72	1.606
2015/8/5	19:45	1.73	1.730
2015/8/5	20:00	1.72	1.606
2015/8/5	20:15	1.72	1.606
2015/8/5	20:30	1.73	1.730
2015/8/5	20:45	1.72	1.606
2015/8/5	21:00	1.72	1.606
2015/8/5	21:15	1.72	1.606
2015/8/5	21:30	1.72	1.606
2015/8/5	21:45	1.71	1.488
2015/8/5	22:00	1.71	1.488
2015/8/5	22:15	1.71	1.488
2015/8/5	22:30	1.70	1.373
2015/8/5	22:45	1.71	1.488
2015/8/5	23:00	1.70	1.373
2015/8/5	23:15	1.70	1.373
2015/8/5	23:30	1.69	1.263
2015/8/5	23:45	1.68	1.158
2015/8/5	0:00	1.67	1.057
Average		**1.86**	**3.713**
Max.		**2.07**	**6.259**
Min.		**1.67**	**1.057**
Total Q in million m^3		**-**	**0.321**

Discharge Measurement FORM-42

Daily mean, Monthly Mean and Annual Mean Discharges

River: ______ Station: ______ E: ______

Year: ______ District: ______ N: ______

Input by: ______ Province: ______ Alt.(amsl): ______

(Unit: m3/sec)

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	9.46	5.63	12.03	6.99	27.67	24.08	19.61	12.93	11.45	8.91	16.66	17.63
2	9.46	5.63	8.15	7.22	27.67	37.85	19.94	12.63	11.16	8.63	16.02	19.61
3	9.18	5.41	7.57	10.30	28.40	51.63	18.77	12.33	10.58	8.15	14.76	28.04
4	8.91	5.41	6.99	12.03	25.14	50.34	17.79	12.33	10.30	7.91	12.63	33.29
5	8.63	5.41	9.18	8.03	25.68	48.64	19.61	11.16	10.01	7.68	11.16	33.29
6	8.38	5.41	13.23	10.45	26.22	45.29	17.30	10.58	9.73	7.45	11.74	26.94
7	8.27	5.19	10.58	9.68	24.78	44.05	17.14	10.87	9.46	7.22	11.45	26.58
8	8.15	5.19	10.87	8.91	25.14	40.78	16.98	10.30	9.18	6.99	12.03	26.94
9	8.15	4.97	10.58	8.38	23.37	39.17	15.23	10.30	9.46	7.45	12.03	26.58
10	7.91	4.97	9.42	8.03	46.96	36.40	14.92	10.87	9.73	7.68	10.58	26.22
11	7.68	4.97	8.27	8.92	43.23	36.40	14.30	12.03	9.46	7.22	10.30	26.94
12	7.80	4.97	8.15	8.63	39.97	33.68	13.68	12.63	9.46	6.99	10.01	28.04
13	7.68	4.75	7.68	8.38	36.79	32.91	27.97	12.93	9.46	6.76	10.30	21.64
14	7.45	4.97	8.15	15.44	40.99	32.91	22.80	12.63	9.46	7.22	10.58	15.70
15	7.22	4.75	7.22	22.50	35.81	42.41	17.63	12.33	9.18	7.45	10.30	14.14
16	7.22	4.32	6.53	29.33	34.84	32.53	17.63	12.33	9.18	7.68	10.30	22.33
17	6.76	5.19	6.19	15.40	34.45	31.01	17.14	12.63	9.18	7.68	10.30	23.72
18	6.76	5.75	5.85	12.33	31.77	29.51	16.82	13.53	9.18	8.63	10.30	22.68
19	6.76	6.30	7.22	11.74	30.26	29.51	16.34	13.53	9.18	8.15	10.30	21.64
20	8.91	4.97	7.22	10.44	33.29	27.67	16.18	13.53	9.18	7.91	10.58	20.96
21	7.95	6.30	6.53	11.16	32.15	26.22	15.16	13.23	9.18	7.22	12.33	20.28
22	6.99	9.46	7.45	11.75	31.39	24.78	14.14	12.93	9.18	7.22	28.04	19.27
23	6.53	8.15	6.99	14.14	30.64	24.08	13.83	12.63	9.18	7.45	30.26	18.94
24	6.30	6.08	7.04	31.18	31.39	23.37	14.45	12.03	9.18	7.91	24.78	18.28
25	6.08	5.96	7.10	21.35	32.15	22.68	14.61	12.03	9.18	7.91	20.28	17.30
26	6.08	5.85	11.16	44.87	48.64	21.98	14.76	12.03	9.18	10.87	22.33	17.30
27	5.85	6.19	6.99	39.77	38.37	21.64	14.76	12.63	9.18	21.64	19.94	16.66
28	5.63	6.53	6.76	34.45	37.39	21.64	14.45	12.33	9.18	18.61	18.28	15.70
29	5.63	12.42	7.45	28.40	41.02	22.33	14.14	12.03	9.18	18.94	18.61	14.76
30	5.63		7.22	26.94	45.09	20.62	14.14	11.74	9.18	19.27	18.61	15.70
31	5.63		7.10		48.36		13.53	11.74		17.63		16.98
Total	228.97	171.08	252.80	497.13	1058.99	976.09	515.72	377.68	285.76	298.37	445.75	674.04
No. of day	31	28	31	30	31	30	31	31	30	31	30	31
Average	7.39	6.11	8.15	16.57	34.16	32.54	16.64	12.18	9.53	9.62	14.86	21.74
Max.	9.46	12.42	13.23	44.87	48.64	51.63	27.97	13.53	11.45	21.64	30.26	33.29
Min.	5.63	4.32	5.85	6.99	23.37	20.62	13.53	10.30	9.18	6.76	10.01	14.14

Annual total discharge:	5,782.4	m3/sec	Annual max. discharge:	51.63	m3/sec
Annual mean discharge:	15.84	m3/sec	Annual min. discharge:	4.32	m3/sec