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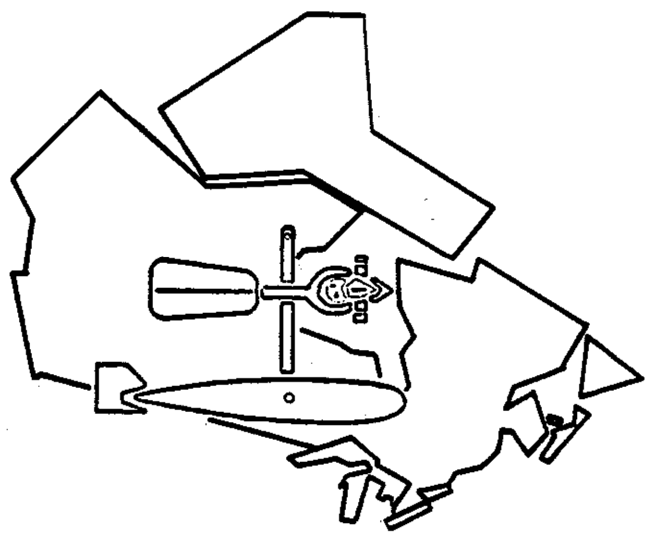
Hydrometric Field Manual — Measurement of Streamflow

R. A. Terzi



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WATER RESOURCES BRANCH
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Contents

Preface

River discharge can be obtained by either direct or indirect methods of measurement. In this section of the field manual, the techniques used by the Water Resources Branch for making direct discharge measurements by current meter are described in detail since this is the fundamental method for measuring streamflow. Various other techniques such as dye dilution, slope-area methods and flow over weirs or dams are sufficiently complex to be the subject of separate manuals.

A portion of this manual deals specifically with the care, adjustment and maintenance of the Price current meter inasmuch as it is the principal instrument used in the determination of river discharge. Other items of equipment and equipment assemblies required for making the various types of direct discharge measurement are also described.

This is the first edition of the "Measurement of Streamflow" section of the field manual. From time to time there will be changes in techniques which may result in suggestions for change to some of the procedures contained in this or other manuals in this series. All such suggestions will be given careful consideration and, if adopted, will be incorporated in subsequent printings of the particular manual.

While this manual and related manuals released by the Water Resources Branch are intended for internal use, they are available on request to any other agencies interested in this work.

This manual was prepared by Mr. R.A. Terzi, Hydrometric Methods Section, with critical comment from regional offices, and approved by Mr. P.I. Campbell, Chief, Water Survey of Canada.

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MEASUREMENT OF STREAM FLOW

Introduction

The Water Resources Branch is the main collector of hydrometric data in Canada, operating and maintaining approximately 2500 gauging stations. Although the primary data collected at these sites are water levels (stage) and river discharges, other observations such as water and air temperatures and ice thickness are made.

The ever increasing demands for hydrometric data are reflected in the many and diverse uses of water to meet today's requirements and to ensure beneficial and wise planning to meet the needs of future generations. The data are essential for engineering schemes involving the safe and economical design of control structures, floodways, storm sewers, culverts and bridges to name a few. At the other end of the scale and equally important, is the need for knowledge of drought flows for the effective and safe management of schemes such as water supply projects, irrigation systems and pollution control programs.

Water Resources Branch field activities are conducted by personnel from regional offices in Halifax, Montreal, Guelph, Winnipeg, Regina, Calgary and Vancouver and from sub-offices administered from these regional offices. Individual field officers are assigned specific areas of responsibility, from these various locations.

Discharge or stream flow is the volume of water flowing through a given cross-section of a stream during a given or implied period of time. The seasonal changes in flow conditions measured at a gauging station result from variations in both precipitation and temperature. Although factors such as elevation, and slope of the watershed, soil conditions and vegetation on the drainage basin will affect the amplitude and duration of runoff, the rate of snowmelt and intensity of rainfall will likely have the most significant affect on fluctuations of stage and discharge.

Stage-Discharge Relationship

A discharge measurement program is carried out to develop a relationship between stage and discharge for the full range of stage. Usually about ten discharge measurements are obtained annually at each gauging station but because of wide variations in Canadian climatic conditions, differences in geographic locations and requirements for specific projects, this number could be less or significantly greater. Each discharge measurement and corresponding water level is plotted and a "smooth" curve is drawn. A graphical illustration of this relationship, called the stage-discharge curve, is illustrated in Figure 1. This is used with a continuous water level record to produce a record of daily discharges. Discharge measurements at periodic intervals are obtained to verify the stability of the stage-discharge relationship. Departure from this relationship may result from scour of the river channel, from backwater due to the formation of ice, the lodgment of ice and debris at the control, alluvial deposits or possibly from a change in slope of the water surface at certain periods during high flow conditions.

EXAMPLE OF A STAGE-DISCHARGE CURVE

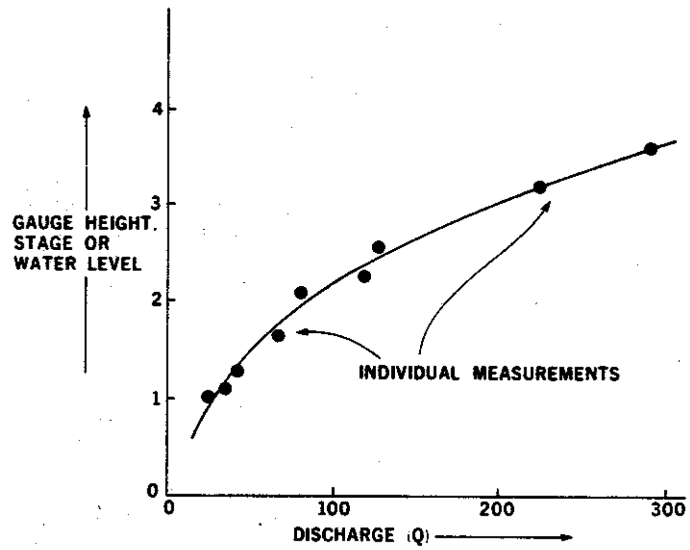


Figure 1

The permanent installation of a gauging station is always preceded by a reconnaissance of the reach of river for which data are required. This is to determine the best location for the proposed station. The choice of location is normally based on an assessment of the physical characteristics of the river channel. These include cross-sectional area, slope, shape and roughness. Once locations for the gauge and measuring section have been selected, the degree to which the stream channel will affect the stage-discharge relationship should be determined. When developing a new stage-discharge curve, or when extending a curve beyond the range defined by measurements, a knowledge of the stream channel characteristics is vital.

A program to obtain a sufficient number of discharge measurements that clearly establish the relationship between stage and discharge is one of the first things to consider for each gauging station. Another important consideration is the stability and sensitivity of the relationship. The full understanding of these parameters is necessary since this is the essential information upon which the production of good records is based.

When developing a new stage-discharge relationship, a number of discharge measurements and corresponding observations of stage must be obtained. The measurements should cover the entire range of stage and be sufficient in number to define all sections of the stage-discharge curve. Over a period of time, a history for the stage-discharge relationship will evolve. At some locations this will have to be verified on a regular basis. At others where it tends to be stable and well defined, it is quite possible that only one or two measurements may be required during the open water period to verify that no change has taken place. This is discussed further in the following section on controls.

A field program should be planned so that trips to gauging stations are scheduled to coincide with changes in stage rather than with calendar dates. For smaller streams where peak flow periods may last for only an hour or so and can occur at any time of the day or night, this can be a particularly difficult task. On the other hand, the duration of high flow conditions on larger rivers is usually sustained, allowing ample time to obtain the required measurements. Of course, most of the rivers and streams measured are neither very large nor very small and the required discharge measurement program must be assessed independently. An offsetting consideration is the additional costs of making several short duration trips to individual sites rather than going on a circuit trip, involving many sites, on a more regular basis.

Control Section

A control is the physical condition at or downstream from the gauge that determines the stability or lack of stability of the stage-discharge relationship. It "controls" or determines the discharge that passes a given point for any given upstream water level. It may be a natural phenomenon such as a stretch of rapids or a weir or other artificial structure. In the absence of a prominent feature, a control may be a less obvious condition such as convergence of the channel or even the resistance to flow through a downstream reach.

The stage-discharge relationship is frequently subjected to many conditions that may or may not be readily apparent. They can significantly change the relationship causing individual discharge measurements to plot either to the right or left of the established curve. These conditions, often caused by impermanent banks, unstable stream beds, or change in slope due to a rising or falling stage, are called shifts and can be of a temporary or permanent nature.

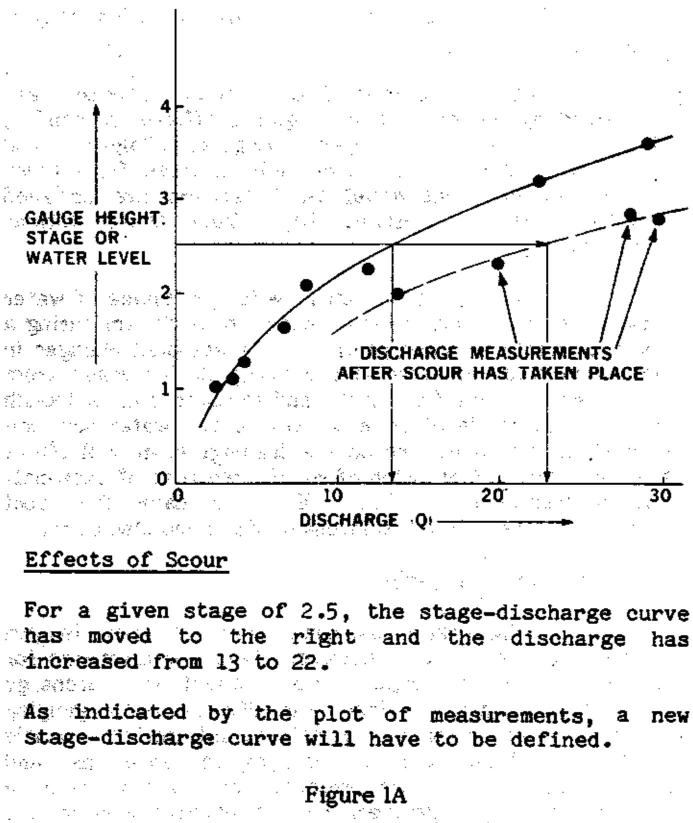
It becomes apparent that, in most instances, a discharge measurement should be made every time a gauging station is visited, regardless of whether or not there has been a change in stage. However, those locations with permanent controls of known stability, that have been adequately gauged, will only require one or two measurements during the open water period to demonstrate that changes have not occurred. Other trips would be necessary to service the recorder and carry out minor maintenance.

During high flow conditions, streams often carry large amounts of debris that can be on the surface or submerged. To attempt a discharge measurement under these conditions can be both time consuming and hazardous and equipment can be lost, damaged or destroyed. Generally, there is a significant reduction in the amount of debris being carried downstream shortly after the peak flow has passed. A proper course of action in some instances may be to wait at the station for a few hours until conditions improve and then proceed with the discharge measurement. It may also be possible to use one of the procedures described in Special Techniques, Measuring High Velocities, as an interim method.

The decisions on when and how to alter a discharge measurement program will depend to a great extent on the background knowledge a field officer has acquired of the area for which he is responsible and on the characteristics of the streams involved.

Scour and Backwater

<u>Scour</u>: Scour is defined as the removal of stream bank or stream bed material by the erosive action of the flowing water. The effects of this will appear as a shift to the right of the stage-discharge relationship as illustrated in Figure 1A. The discharge capacity of the stream will increase over that which it was earlier capable of, for the same given stage.



<u>Effects of Scour</u>

For a given stage of 2.5, the stage-discharge curve has moved to the right and the discharge has increased from 13 to 22.

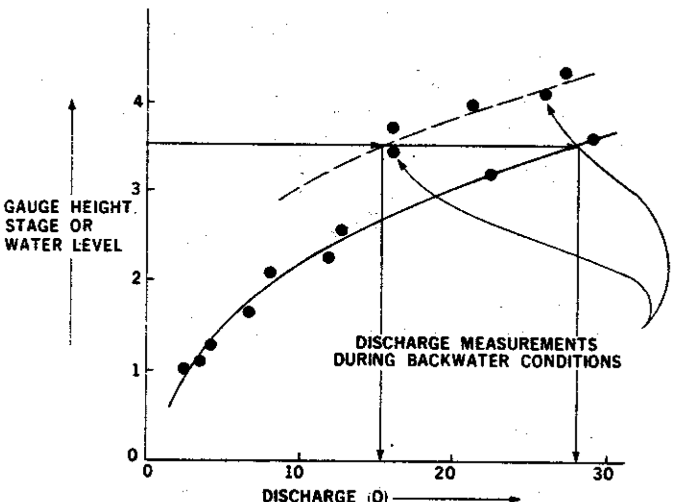
As indicated by the plot of measurements, a new stage-discharge curve will have to be defined.

Figure 1A

Changes to stage-discharge relationships can take place in a gradual and continuous manner as a result of slow processes of erosion or they may occur suddenly as a consequence of more profound alterations in the channel. They can be caused by high flows or they can result from the scouring action of ice. Generally these changes will be most apparent at low and medium stages and least noticeable during high flow conditions.

The field officer must be prepared to obtain discharge measurements on a frequent basis to determine the rate and magnitude of any change. During and after extreme events, such as floods, it may even be necessary to redefine the entire stage-discharge curve.

Backwater: Backwater is the condition where the water in a stream is backed up or retarded in its course as compared with its normal or natural condition. Backwater effects will appear as a shift to the left of the stage-discharge relationships and, for any given stage, there will be a corresponding decrease in discharge. This is illustrated in Figure 1B.



Effects of Backwater

For a given stage of 3.5, the stage-discharge curve has moved to the left and the discharge has been reduced from 28 to 15.

Figure 1B

Although there are a great number and variety of conditions that can cause backwater conditions, the three most common result from debris lodged in a stream channel or on the control, from the growth of aquatic vegetation in the channel or from the formation of ice cover. Backwater conditions can also result from high water levels in a lake or reservoir downstream of the gauge or from high flows in a downstream tributary.

Debris Effects

Debris or drift material lodging in the stream channel or on the control does not normally cause a backwater condition on large streams. One exception is a large stream that is subject to a large amount of material such as in the case of a logging operation. For smaller streams, it is often possible to remove or dislodge debris that is affecting the stage-discharge relationship. Once this is done, carefully note and record the effects. A similar but opposite effect may be evident on earlier records to indicate how long the relationship has been affected. The information will be useful when computing daily discharges for the period in question. Allow flow conditions to stabilize before obtaining a discharge measurement.

Aquatic Growth Effects

The problems created by the cycle of aquatic growth and decay in a stream channel are twofold. The growing vegetation not only creates backwater by decreasing the capacity of a stream channel, it also affects the accuracy of discharge measurements by disturbing the distribution of velocities in the vertical and impeding the operation of the current meter.

Aquatic growth begins when water temperatures rise in late spring or early summer and continues until the fall when the water temperatures lower. Throughout this period, a program of frequent discharge measurements must be carried out in order to establish the changes to the stage-discharge relationship.

Since it is often difficult to obtain accurate velocity observations under these circumstances, special care must be taken during the measurement of discharge in order to minimize the effect of velocity disturbances at lower depths. In some instances, the best results can be obtained by using the three point method of velocity observation. With this method, the mean of the velocities observed at 0.2 and 0.8 of the depth are averaged with that observed at the 0.6 depth.

Ice Effects

Three distinct types of ice can form in a flowing stream and reduce the carrying capacity of the channel:

1) Board Ice - an apparently uniform ice cover formed at the ice-water interface, usually starting at the edges where the water is shallow and progressively working towards the centre of the stream.

2) Anchor Ice - submerged ice attached to the river bottom.

3) Slush Ice - a combination of frazil ice (fine spicules of ice suspended in water), anchor ice that has become detached from the river bed and shale ice (thin brittle skim ice plates).

Although any of these conditions can develop independently from the others, the formation of ice in a stream most often involves the combination of all types of ice.

Although the initial stages of ice development can be gradual, with little to indicate that a backwater condition exists, the opposite is more often the case, and is characterized by the formation of ice that obstructs the flow of water both below and above the gauge, and causes abrupt fluctuations in stage with correspondingly large changes in discharge.

As the ice cover forms, the discharge capacity of a stream channel is reduced due to the increased friction caused by the ice surface. If the underside of the ice cover is particularly rough or if there is an accumulation of slush ice, the backwater will increase accordingly. After the initial development of ice cover, the flowing water will tend to erode the ice and thereby reduce the friction and the amount of backwater. This can and often does take place over a prolonged period of time and the result from any reduction in friction will often be offset by an increase in ice thickness due to progressively colder temperatures.

River discharge during the formation of ice is usually difficult to define because of rapidly changing backwater and the storage and release of water as the channel becomes alternately clogged and freed from accumulating ice. Although it is most often a difficult task, discharge measurements should be obtained during this period.

Normally the easiest winter discharge measurement to obtain is one by wading, provided that enough ice cover can be removed from above and below the cross-section to minimize any effects on the velocity distribution. Where rivers are not wadeable, a partial measurement from a bridge or cableway should be considered even though sections of the river may be ice covered. If the ice is unsafe to walk on preventing a part ice cover and part open water measurement, sections of flow may have to be estimated. Notes from previous measurements can be used to assist in estimating the cross-sectional areas covered by ice.

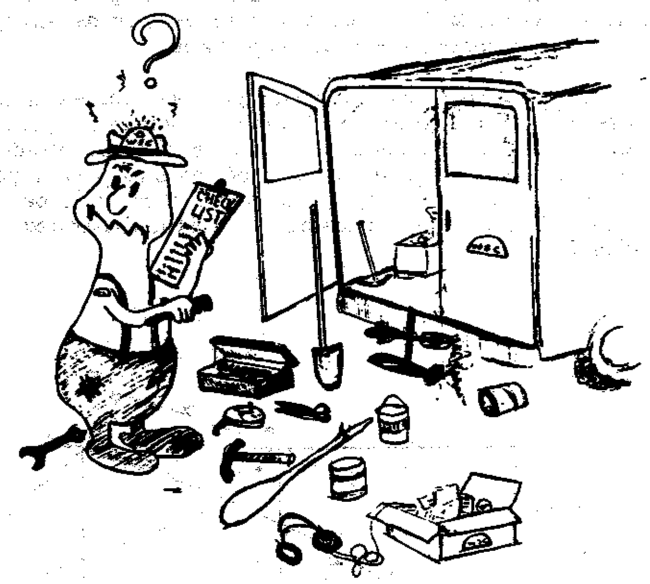
DISCHARGE MEASUREMENTS

Pre-Trip Plan

A standard procedure to follow prior to every field trip is to prepare a pre-trip plan. Normal or routine maintenance and supply problems are considered at this time. Necessary repairs to shelters, cable cars and cableways, which were not completed during a previous field trip or perhaps required supplies which were not readily available, should be listed in the Field Data Book.

Experience has shown that unless a definite effort is made to organize this information and material in advance of each trip, some items necessary for the survey will be inadvertently excluded from the planning. An experienced field officer will have developed a system whereby pertinent notes are kept for this very purpose. An excellent location for notes of this type is the Field Data Book. It is a decided advantage to have all the necessary information related to the gauging stations for which the field officer is responsible, readily accessible for field use.

Another application when the Field Data Book can be of value is during floods or high water. At these times it is often necessary to deploy extra personnel on short notice to obtain proper coverage of an event and there is usually very little time to assemble and provide them with information pertaining to the location of gauging stations, station bench marks and elevations, measuring sections and cableways. When these data are compiled in one field book, they are readily available to be copied or removed and distributed to field officers who are not familiar with the gauging station locations.



A HAPHAZARD LIST WILL ONLY LEAD TO UNNECESSARY DELAYS AND CONFUSION.

FIELD DATA BOOK

The "Field Data Book" (Figure 2) is a most important record for a field officer to maintain. Levelling results, a list of measurements for the current year and notes on conditions which may affect the stage- discharge relationship should all be recorded in this book. Information dealing with maintenance for both structures and the instrumentation at each gauging station site should be listed as well. Any instruction dealing with special instruments, equipment or unusual techniques must also be included. The book should contain the following information for each station:

1) a copy of the station description complete with a good quality detailed map; bench mark locations and elevations

2) a print of the current stage-discharge table (form R42);

3) a copy or plot of the stage-discharge curve (on 11" x 17" form R239A);

4) a sheet on which to list discharge measurements (form R56);

5) stage-discharge curve deficiencies;

6) location and description of low, medium and high water metering sections;

7) a sheet to record level checks;

8) special instructions - instrumentation, equipment, maintenance, etc.

9) name and address of gauge observer or attendant.

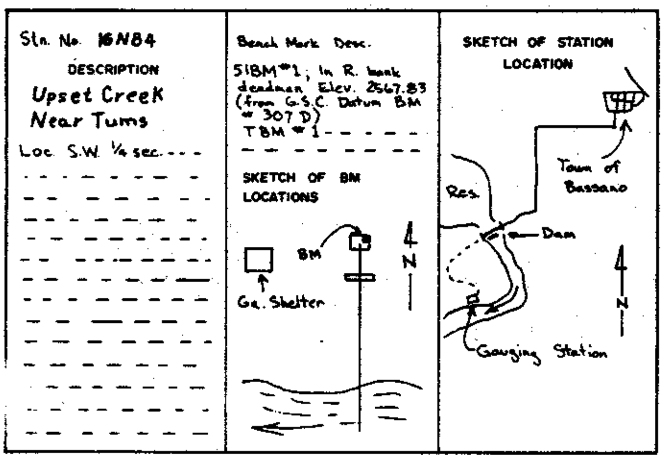
The stage-discharge curve must be prepared in accordance with the instructions contained in the "Manual of Hydrometric Data Computation and Publication Procedures", so that the extreme high and low discharge measurements from previous years are plotted on a replica of the current stage-discharge curve. Normally, all discharge measurements must be computed prior to leaving the vicinity of the gauging station. This will allow for a check measurement to be made should it prove necessary. During conditions of open water, plot the unchecked computed results on the field curve in the data book, using the latest gauge correction.

This current and pertinent information is not only useful when preparing a pre-trip plan, it also provides the necessary background information on which to base decisions which must be made while in the field.

Pre-Measurement Procedures

Before proceeding with a discharge measurement, the gauge reading and time should be observed and recorded. This is particularly important where the station is equipped with only a manual gauge, since an accurate determination of the mean gauge height is essential for plotting the results of the discharge measurement. If there appears to be a change in stage while the measurement is in progress, it will be necessary to obtain additional readings during the progress of the measurement.

Where a gauging station is equipped with a water level recorder, the stage record which has been accumulating since the time of the previous visit is removed from the recorder prior to beginning the measurement. Where the station has a stilling well, the intakes must be flushed; if equipped with a servo-manometer, adjustments may be required. Wind the



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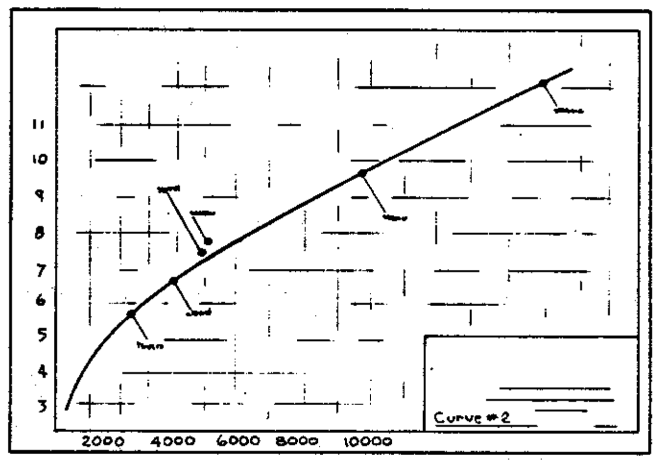
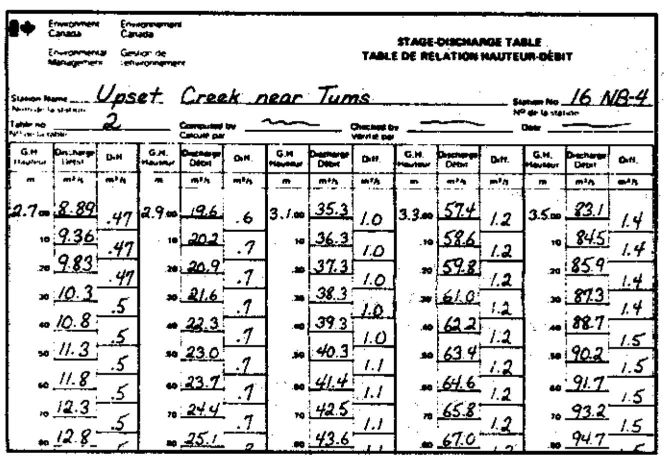
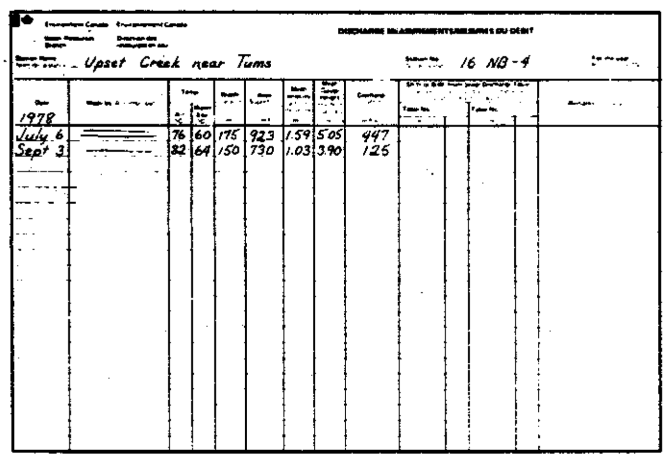


R 239 A



G.H. Hauteur (m)	Discharge Débit (m³/s)	Diff. (m³/s)	G.H. Hauteur (m)	Discharge Débit (m³/s)	Diff. (m³/s)	G.H. Hauteur (m)	Discharge Débit (m³/s)	Diff. (m³/s)	G.H. Hauteur (m)	Discharge Débit (m³/s)	Diff. (m³/s)	G.H. Hauteur (m)	Discharge Débit (m³/s)	Diff. (m³/s)
2.700	8.89	.47	2.900	19.6	.6	3.100	35.3	1.0	3.300	57.4	1.2	3.500	83.1	1.4
10	9.36	.47	10	20.2	.7	10	36.3	1.0	10	58.6	1.2	10	84.5	1.4
20	9.83	.47	20	20.9	.7	20	37.3	1.0	20	59.8	1.2	20	85.9	1.4
30	10.3	.5	30	21.6	.7	30	38.3	1.0	30	61.0	1.2	30	87.3	1.4
40	10.8	.5	40	22.3	.7	40	39.3	1.0	40	62.2	1.2	40	88.7	1.5
50	11.3	.5	50	23.0	.7	50	40.3	1.1	50	63.4	1.2	50	90.2	1.5
60	11.8	.5	60	23.7	.7	60	41.4	1.1	60	64.6	1.2	60	91.7	1.5
70	12.3	.5	70	24.4	.7	70	42.5	1.1	70	65.8	1.2	70	93.2	1.5
80	12.8	[illegible]	80	25.1	[illegible]	80	43.6	[illegible]	80	67.0	[illegible]	80	94.7	[illegible]

R 42



1978									
July 6		76	60	175	923	1.59	5.05	447	
Sept 3		82	64	150	730	1.03	3.90	125	

R 56

Figure 2

clock drive mechanism of the recorder and set the pen to the correct time and gauge height and proceed with the discharge measurement. When the measurement has been completed, obtain another gauge reading and observe whether the recorder drive system is operating properly and if the pen is tracking correctly. By this time the recorder will have been operating for approximately one hour and any error in setting the pen should be readily apparent. This is also the time to check the recorder drive system to make certain that the clock weight spring hasn't caught on the shelf or that the ratchet and pawl of a negator spring-driven recorder is disengaged.

Where an automatic recording installation is equipped with a manometer, make certain that the following additional steps have been completed before leaving the site.

1. Observe both the pressure in the cylinder and the reduced pressure being supplied to the manometer. Record the information on the log sheet or on the measurement note form as required.

2. Make certain that the appropriate valves to the manometer are either fully open or fully closed. (see Field Manual - Measurement of Stage).

3. Check the voltage of batteries under load conditions.

4. Make sure that the delay switch on the servo-control unit is in the correct position (this is normally the maximum position).

5. Replace the cover or covers being careful not to pinch any of the tubing in the process.

The need for servicing the recorder and manometer in this order cannot be stressed enough. The time taken to check the operation of the recorder and other instruments before leaving the gauging station should reduce significantly the number of record loss events.

SUMMARY

1) Read all gauges or obtain a water level by instrument. Note and record any difference. (Pen setting, gauge height or water level.)

2) Flush the stilling well intakes and make certain they are in no way obstructed. Note and record any difference that may have occurred after flushing.

3) Service the recorder.

4) Make any adjustments to the servo-manometer that may be necessary - float switch adjustment, check for gas leaks, check valve positions.

5) Level check the gauge or gauges if required.

6) Complete all notes on observations made or procedures followed thus far.

Before using a current meter, it should be inspected so that the bearing surfaces are in good order. This can be done quite easily by first loosening the bucket wheel raising nut so that the pivot wheel bearing rests on the pivot. The bucket wheel is then gently rotated and observed as it comes to a stop. If the stop is gradual then the bearing surfaces and the pivot are in satisfactory condition. If the bucket wheel comes to an abrupt halt, the pivot and bearings should be closely inspected. If there is evidence of wear, the meter should not be used but should be returned to the rating facility for overhaul, and perhaps, an "as received" calibration.

7) Obtain the discharge measurement.

8) Check the recorder operation, manometer or stilling well intakes.

Assessing River Conditions

Having completed the pre-measurement procedures, the next step is to assess the river conditions. Observe carefully and make the necessary notes describing conditions which are or could have affected the stage-discharge relationship since the time of the last visit to the station. Look for and describe such conditions as weed growth at the measuring section or on the control, debris floating or lodged in the proximity of the gauge, beaver activity, the deposition of gravel or development of sand bars in the vicinity of the gauge or erosion of the river banks. In the event of high flows, look for any overflow channels. Overbank flows that are bypassing the metering section must be measured or estimated. Obtain photographs of unusual conditions if at all possible, as these are often valuable for later reference. Construction in the vicinity of the gauge, or high winds, should noted. During winter periods, the description conditions, amount of ice cover, ice jams, flowing slush and overflooding of the ice cover should be noted. The completeness of these notes will not only aid in making judgement decisions when computing the records, but can be of inestimable value for detailed studies at a future date.

There are times when it is quite in order, and indeed advisable, to forego a discharge measurement at a gauging station. For example, when unsafe ice conditions prevail or when a stream is heavily laden with debris, it would be both unsafe and impractical to obtain a complete measurement. A field officer may also pass up a measurement at one station when to obtain a measurement or observe unusual or extreme conditions at another station is of higher priority.

Conducting the Measurement

Discharge measurements are usually made using one of two methods which are generally described as direct and indirect methods of measurement. The main difference between the two methods is the manner in which the value for the velocity is obtained. A direct measurement is one in which discharge is measured at the time of its occurrence while for indirect measurements, the discharge is determined after the event has passed.

Indirect methods, where the average velocity is computed from formulae, observed by a single-point device or obtained by other special techniques, are sufficiently complex to be the subject of separate chapters of the Field Manual and therefore are not covered in this manual.

The direct method of measurement most commonly used by the Survey is the velocity-area technique whereby the computed discharge of a stream is the product of the cross-sectional area and the average velocity. The measuring or metering section is divided into a number of sections, usually twenty, each bounded by two adjacent verticals. The distance along the measuring section to each vertical is referenced to a permanent initial point located on either shore. During a discharge measurement, observations of depth and velocity at each vertical will progress from one shore to the other. The distance between verticals along the measuring section will depend largely on the following factors:

1) the overall width of the stream

2) the unevenness of the stream bed

3) the variation of velocities across the channel.

It is important to space the verticals more closely where the depths and velocities are more variable in order to define accurately the discharge for any given segment. Where the variation of depth and velocity between verticals is gradual, the spacing can be greater. Unless specified otherwise, a minimum of 20 verticals at which to observe depths and velocities should be selected at any measuring section. The distance between consecutive observation verticals should be such that the discharge in any one panel would be appropriately 5 percent of the total discharge. These two criteria may not be possible for very narrow streams where the verticals would be less than 0.15 m apart, a Pygmy meter should be used rather than the customary Price No. 622 meter in order to obtain a greater number of sampling points. The small bucket wheel will also respond more readily to low velocities.

GENERAL METERING CRITERIA

The criteria to be followed when making a discharge measurement are as follows. Reference to the diagrams with "Discharge Measurement Computations", will be useful when reading the following paragraphs:

(1) The location on a river where a measurement is taken is called the "metering section". If at all practicable, all measurements should be taken at the same metering section. This of course will vary and with changes in stage, what might be an ideal section for measuring high and medium flows from a cableway, boat or bridge, may be far from acceptable for making low water wading measurements. However, once the sections for wading, medium and high water measurements have been selected, they should not be changed unless there is a substantial reason for doing so.

(2) All observations of distance at metering sections shall be referenced to an initial point on the shore. This should be a well defined immovable object which in turn is referenced to a permanent feature in the vicinity of the measuring section or gauging station. These data are often required for detailed studies long after the gauging station has been established or possibly even discontinued.

(3) The metering section chosen should be perpendicular to the general direction of flow, a procedure for determining angle of flow corrections is described in Special Techniques, "Correcting for Angular (Oblique) Flow". It should also be located in a reach of the river where the bed and banks are straight and uniform for a distance of approximately five times the section's width upstream and a distance of approximately twice the width downstream.

(4) The stream bed cross-section should be as uniform as possible and free from vegetal growth. Large rocks and protruding obstructions such as bridge piers are particularly objectionable although not always avoidable.

(5) There should be a minimum of 20 to 25 observation verticals in the cross- section in addition to the 2 points which define the edges of the channel.

(6) The observation verticals must be distributed in relation to depths and velocities so that any unevenness of the river bed and significant variations in velocities are well defined. Verticals should be more closely spaced where depths and velocities are greater or highly variable. If the verticals are properly spaced, then the discharge in each of the sections should be about 5 percent of the total discharge.

(7) Before the start of a velocity observation, allow sufficient time for the current meter to adjust to the velocity being measured. The adjustment time required will be a very few seconds at high velocities and significantly longer at low velocities. This adjustment period is of particular importance at low velocities, those of 0.3 m/s or less and the failure to observe it could produce erroneous velocity measurements.

(8) Observe velocities for 40 to 80 seconds.

(9) Observe time to the nearest 1/2 second.

(10) The 0.2 and 0.8 depth method is normally used when obtaining the mean velocity in a vertical. This is based on both mathematical theory and from studies of actual observations from numerous vertical velocity curves. See Fig. 3 for a typical vertical velocity curve.

(11) For measurements where depths are 0.75 m or less, observations are made at the 0.6 depth. Experience has shown that the use of the 0.2 and 0.8 depth method in shallow streams places the current meter too close to the water surface and the stream bed to give reliable results.

(12) When sounding, whether from bridges, cableways, boats or when wading, record soundings to the nearest 2 cm.

(13) See "Discharge Measurements During Ice Conditions" for winter measurement procedures.

TYPICAL VERTICAL VELOCITY CURVE

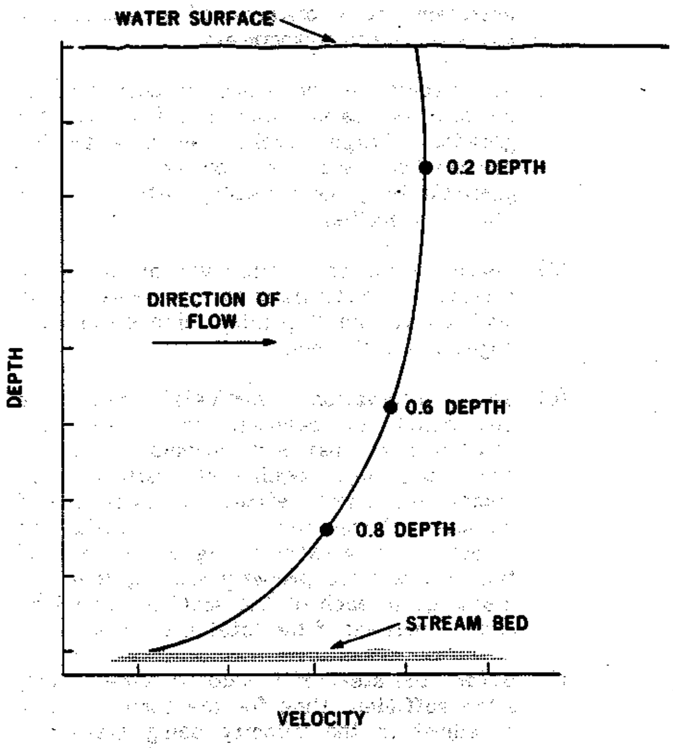


Figure 3

MEASUREMENTS BY WADING

Where conditions permit, wading measurements are preferred to those obtained by other means. They offer the possibility of selecting the best available cross-section for the measurement as well as simplicity in making the observations and computing the discharge.

In preparation for a wading measurement the type of current meter to be used must first be determined. Where the selected measuring section is either very narrow and shallow or where the majority of depths are 0.15 metre or less, the Pygmy meter should be used. The Price No. 622 meter tends to over-register if the buckets are only partially submerged and should only be used where depths are greater than 0.15 metre.

When the meter has been attached to the wading rod and the electrical lead on the rod connected to one of the terminals on the meter contact chamber, the electrical circuit is now ready for testing. Attach the headset, beeper or counter to the receptacle at the handle of the rod and rotate the bucket wheel. If a headset or beeper is used, a series of sharp clicks or beeps should be heard. With a counter, the digit dial will rotate in the viewing window.

If the station has been in operation for some time, there is usually a standard location at which wading measurements are made. Nevertheless it is wise to inspect the reach immediately above and below this location to make certain that the standard location is indeed the most suitable for the measurement.

Be careful when deciding whether or not conditions at a station will permit the stream to be waded in safety. A general rule of thumb which has been used in the past is arrived at through the product of the depth and velocity. Generally speaking, if the stream bed is firm and provides good footing, the product of these two factors should be slightly less than 1 for safe conditions.

To begin the measurement a tag line must first be placed across the stream. If not familiar with the section, it is advisable to make a careful preliminary crossing before stringing the tag line. Anchor one end of the tag line at the initial point and proceed across the stream stringing the tag line at right angles to the direction of the current. Use the wading rod as a support when crossing the stream but first raise the current meter high on the rod. If the section is totally unfamiliar, use the rod without the meter when making the initial crossing. This is done for two reasons. Should it be necessary to move the rod quickly because of poor footing, there is little likelihood of striking a submerged rock and damaging the meter; secondly, there is much less resistance to the current if the meter is out of the water or not on the rod at all.

While wading across the stream to place the tag line, an overall impression of the depths and velocities can be obtained. This is also a good time to look for rocks and debris which might be removed from the stream bed to improve the measuring section. Be certain, particularly for very small streams, that the rocks to be removed do not form part of the control. Once the tag line has been secured and the overall width is determined, it is then possible to decide on the distribution of observation verticals and to proceed with the measurement. The banks of the river and corresponding edges of water are always defined as right or left bank (R.B. — L.B.), or right or left edge of water (R.E.W. — L.E.W.), when facing downstream.

Record the starting time. Next, record the edge of water distance by observing the appropriate numbered marker on the tag line. If there is a vertical drop at the edge, an observation of depth and velocity must also be obtained. Move to the position selected as the next vertical and record the distance indicated by the numbered marker on the tag line. Observe and record the depth. Next, set the current meter to the correct depth to obtain the velocity. In order to obtain the velocity, count and record the number of revolutions the bucket wheel makes for a duration of time between 40 and 80 seconds. Observe and record the time to the nearest 1/2 second. In order to use the current meter rating table, the number of revolutions counted should be one of the 13 that are listed. Current meter rating tables are so designed that the velocity in meters per second can be obtained directly, for a given number of revolution within the required time frame. The 13 choices of pre selected revolutions are 5, 10, 15, 20, 30, 40 50, 80, 100, 150, 200, 250 and 300. If this method is not used, a double interpolation of both time and count is necessary to use the table to compute velocity. This procedure is repeated until the stream is traversed and the measurement is completed. Upon completion, note and record the time.

Although wading measurements allow for greater control over the discharge measurement procedure, lack of attention to detail and errors in technique which would otherwise be considered as minor for larger flow conditions, can have a significant affect on the overall accuracy of a measurement. Therefore when making a wading measurement the following steps should be followed carefully:

1. Take the time to ensure that the tag line is placed in a position that is perpendicular to the direction of the current. Even though this precaution has been taken there will be instances where angular flow occurs. When this does happen, record the cosine of the horizontal angle. This is described completely in the section "Correction for Angular Flow".

2. Where necessary, take the time to improve the measuring section by removing boulders and debris from the measuring section and the area immediately above it. Remove weeds for a distance of about 3 times the depth from the area upstream and downstream from the section. On smaller streams it may be possible to construct small dikes to cut off sections of shallow flows and dead water. After any modifications of this sort, be certain to allow sufficient time for conditions to stabilize before proceeding with the measurement. Also note if these modifications have had an influence on the gauge reading.

3. Obtain 20 to 25 observations of both depth and velocity for one complete measurement (See Discussion of Errors). Where a narrow cross-section is encountered, verticals should not be spaced closer than 0.15 m when using the Price No. 622 meter, since the distance between verticals must be greater than the diameter of the current meter bucket wheel. Where a very narrow section is encountered, it is often preferable to use a Pygmy meter and space the verticals closer.

4. The position of the field officer with respect to the current meter is very important when making a discharge measurement by wading. The field officer should be to the side and downstream from the meter so as not to influence the velocity being measured. Exhaustive studies have indicated that the position which has minimal effect on the operation of the current meter is when the officer stands facing either shore and is no less than 0.4 m downstream and to the side of the current meter.

5. Hold the wading rod in a vertical position and the current meter parallel to the direction of flow while the velocity observation is being made. If the axis of the meter is not kept vertical, the meter will tend to under-register.

6. If depths are sufficient, the 0.2 and 0.8 method should be used for observing velocities. The settings on the wading rod for these observations can be made quite easily. To set the 0.2 depth position on the rod, simply double the value of the observed depth. The 0.8 depth position is determined by setting the value of one-half the observed depth on the rod. Example: observed depth 0.96 m: for the 0.2 depth set 1.92 on rod, for the 0.8 depth set 0.48 on rod. It should be pointed out that the 0.2-0.8 method is not entirely satisfactory where stream beds are very rough, irregular or covered with aquatic growth. These conditions will often produce erratic results for the observation at the 0.8 depth. In some situations, more reliable results have been obtained by computing the average velocity on the basis of the 0.2 and 0.8 depths and averaging the computed value with the velocity from the 0.6 depth.

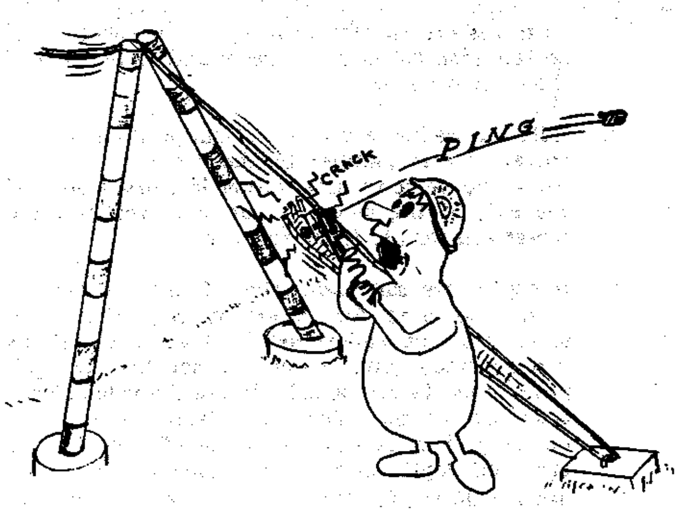
7. Sounding stream beds that are extremely soft or those that are boulder-strewn requires a great deal of extra care and attention. Be careful not to over-sound by allowing the bottom of a wading rod to sink into soft stream bed material when sounding or obtaining velocity observations. When sounding very rough stream beds, such as those with very large boulders, take time to adjust the observed depths so that they reflect both the tops of the boulders and the deeper depths between them.

CABLEWAY MEASUREMENTS

Cableway measurements are generally preferred to those from boats or from bridges with piers. The lengthy set-up time required for boat measurements is eliminated as are areas of disturbed flow caused by bridge abutments and piers. For these and other reasons, the use of cableways by the Water Survey is becoming more common for rivers up to approximately 450 m in width.

Periodic safety inspections must be carried out at all cableway sites (See Safety Guide - Construction and Operation of Stream Gauging Cableways). In areas where the potential for vandalism is great, these inspections should be frequent. Cable car sheaves and locking devices as well as clamps and turnbuckles for both the main cable and tower tie-back cables must be checked carefully. Cable clamps are a prime target for vandals and should be checked before each crossing.

The main cable should be maintained at the proper sag. Because the length and therefore the sag will change with variations in temperature, seasonal adjustments of the cable may be necessary, particularly



CHECK CLAMPS

those of longer spans. To prevent undue strain or stretching during the winter months, the tension should be reduced by backing off the turnbuckles in the autumn.

Adjustments to a cableway should be made prior to spring and summer use. Unnecessary sag makes the operation of the cable car more difficult because of the increased slope in the cable when either tower is approached. This becomes significant with long cables where heavy cable cars or those heavily loaded with equipment are hand propelled. In most cases, once the correct sag has been determined, permanent reference marks can be painted on the cable support structures. It is then a simple matter of sighting between these marks and the bottom of the cable any time a sag adjustment is required. (Figure 4)

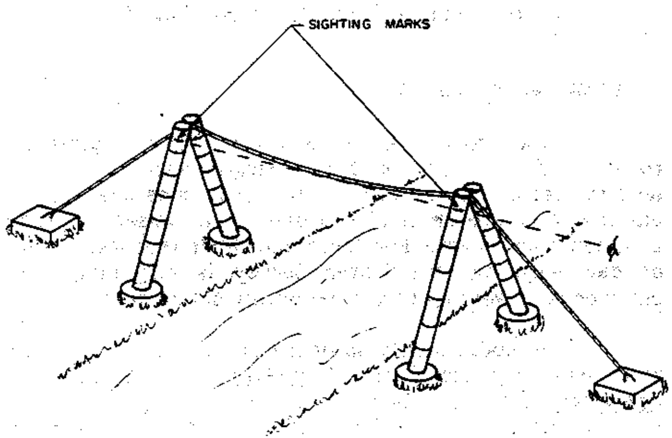


Figure 4

A cable car moving on the cable, should never be permitted to travel too rapidly. Dirt and grit, paint chips and splinters of metal produced by the abrasive action between the cable and the rapidly rotating sheaves can cause serious eye injuries to anyone riding in the car. Glasses or some other form of eye protection should be worn.

A pair of good quality side-cutting pliers must be carried when making measurements from cableways. Should the meter and weight assembly become caught in submerged or floating debris that cannot be dislodged or towed to the shore and removed, the sounding cable should be cut to ensure the safety of the cable car occupant. Record the distance from the initial point at which this occurred. This may be helpful if and when an attempt is made to recover the equipment.

Procedure

Mount a sounding reel on a metering frame if required and secure the assembly to the cable car. (Some cable cars are equipped with permanent reel mounts). Assemble the current meter and sounding weight on the hanger. The recommended minimum depths for positioning current meter when using the M-2 hanger bar with various weights is shown in Table 1. Since the purpose of the weight is to maintain the sounding line in a position as near to vertical as possible in order to measure depths correctly, select the proper weight for the depths and velocities to be measured. Information from previous measurements should be listed in the Field Data Book or plotted on the field curve and can be used as a guide for the size of weight required at various stages. In some cases this is not available and will have to be obtained by trial sampling. Your experience will determine whether this step is necessary.

Table 1

Minimum depths for positioning the current meter when using the M-2 hanger bar with various weights

Sounding Weight	0.6 depth Method	0.2 & 0.8 depth Method
15 and 30 lb.	0.55 m	1.15 m
50, 75 and 100 lb.	0.80 m	1.60 m

Conditions will be encountered where the weight is insufficient and the drag on the sounding line and weight will cause them to be deflected downstream. Even though it is simpler to use a heavier weight than to compute corrections to determine correct depths, these weights are not always readily available or on occasion even the heaviest weight will be deflected. One of the three methods discussed in Special Techniques (Sounding) must be used to obtain correct soundings.

No attempt should be made to carry heavy sounding weights up an access ladder to a cable car platform. Unwind a sufficient amount of cable from the mounted sounding reel to permit the meter and weight assembly to be attached to the cable at ground level.

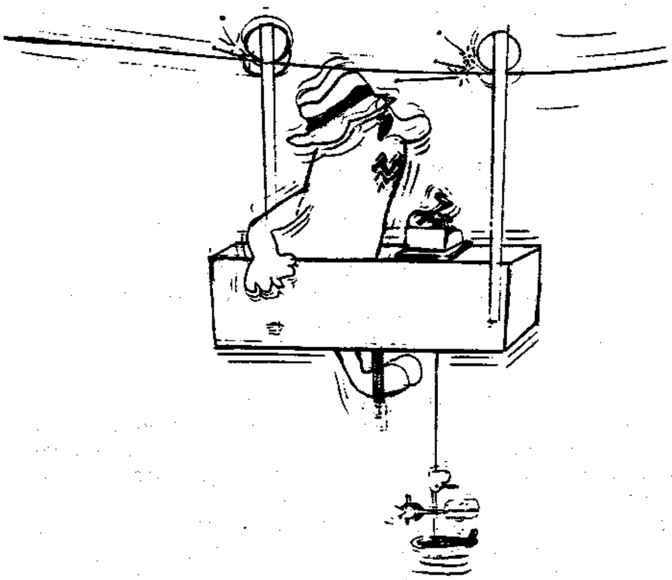
With the equipment assembled and mounted on the cable car, connect the headphones to the sounding reel jack and spin the current meter bucket wheel to make certain that proper contact is being made between the brush and slip ring on the sounding reel and in the current meter contact chamber. Now check the items required during the measurement; stop watch, note book and paper (remove any notes from previous measurements), pencils, sidecutting pliers and screw driver, cable car puller and brake.

Next, record the size of weight and the position of the meter above the bottom of the weight. The initial point for cableway measurements is usually located at one of the towers. In order to remove the possibility of confusion, the left bank tower or anchor should always be selected for the initial point. This will also prove to be an added convenience if and when it becomes necessary to plot channel profiles at the measurement section, since these are normally prepared as downstream views. The initial point should be marked in an unmistakable manner since all distances, observations of depth and velocities must be referenced to this point. The distance between the spacings painted on the main cable should also be marked on this tower. This information must be included in the Field Data Book.

Board the cable car and proceed to the edge of water to begin the measurement. A rope can be used as a simple brake to control the movement of the cable car see Figure 5B. Record the distance from the initial point to the water's edge, the starting time of the measurement and record the bank at which the measurement is started.

Soundings are usually made with the meter at the water surface, that is, with the bottom half of the bucket wheel submerged and the horizontal section of the tail assembly at the water surface. The distance between the meter and the bottom of the weight must be added to the soundings indicated on the reel counter to obtain the correct depth. The slight amount of drag on the meter and weight when the "meter is zeroed" has a stabilizing effect which makes the process of sounding quicker and easier than when attempting to "zero" the bottom of the weight. There is also the convenience of not having to apply a correction each time the meter is positioned in the vertical.

Observe and record soundings to the nearest 2 cm at each vertical. Be careful not to over-sound by allowing the sounding weight to sink into a soft or unstable stream bed. The distribution of verticals must be in accordance with that outlined in the section on "Metering Criteria". Also see the paragraph "Tagging the Line", for sounding in deep, fast flowing water.



Some cables may undulate from the pulling motion required to move the cable car from one vertical to the next or from vigorous cranking movements when sounding with heavy weights. This motion must be allowed to subside before starting the depth and velocity observations. This is of particular importance when measuring velocities below 0.75 m per second, since the effects of vertical movement on the current meter are most significant in this range. Observe and record the time and revolutions of the current meter bucket wheel.

The cable car can be held stationary during the measurement by jamming the belt attached to the car puller under one of the car sheaves. Another method using a short length of rope is illustrated on Figure 5A.

At the end of the measurement, record in the notes the time of completion and an appropriate remark identifying the edge of the channel. Record any pertinent information that may have had an effect on the measurement results.

USING A ROPE TO CONTROL CABLE CAR SPEED

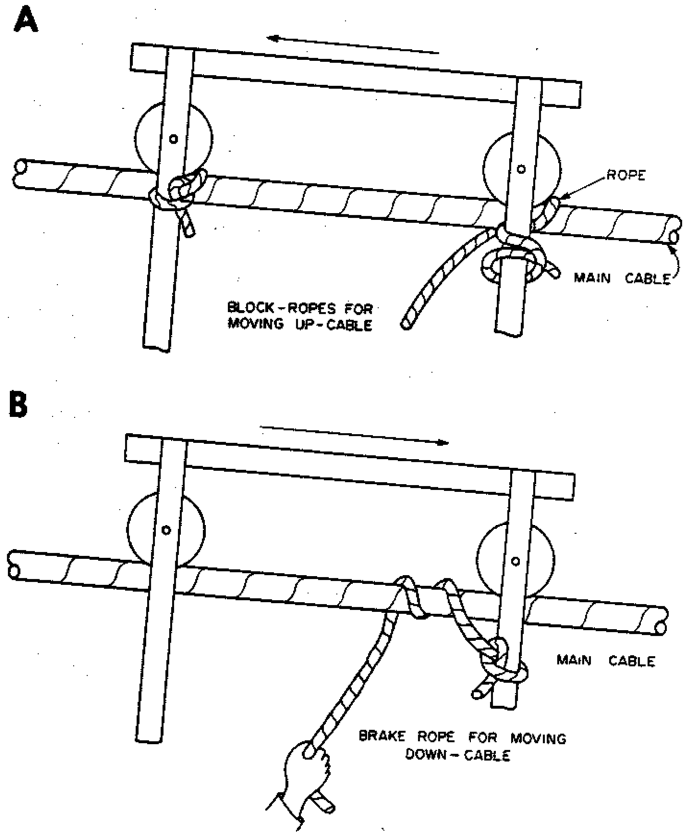


Figure 5A - 5B

BRIDGE MEASUREMENTS

Bridges are not the most ideal structures from which to make discharge measurements but, for reasons of economy, they must often be used. Piers can cause changes in velocity, angular flow, scour and deposition which all add to the difficulty in making a measurement and if care is not taken, the accuracy of the measurement will be affected. Old pilings and debris lodged around the piers can also be particularly troublesome.

The downstream side is usually preferred when metering from a bridge. Piers tend to straighten the flow lines and if necessary vertical angles of the suspension cable can be measured more easily. The suspension cable is also kept from rubbing against the bridge deck or bridge members. However, there are disadvantages, such as not being able to readily spot floating debris or ice and having to sound and measure velocities in the turbulence caused by piers.

One of the abutments is normally chosen as the initial point for bridge measurements. As in the case of cableways, this should be on the left side of the stream whenever possible. There is an understandable objection to having marks painted on bridges, particularly the newer ones. It is therefore essential that information describing the initial point and the distance between sounding verticals be recorded in the basic field data book. In place of permanently painted reference marks for sounding, a tagline can be strung from the initial point along the bridge deck to obtain the distance between verticals. Where it is permissible to paint marks on the bridge rails this should be done in a neat and orderly fashion with the paint marks on the outside (stream side) of the rail so as not to invite unnecessary criticism for defacing property.

Procedure

Select and assemble the equipment required for the measurement. In most cases a bridge frame and type A reel can be used with weights of 75 pounds or less (They can on occasion be used with 100 pound weights). The type A crane on a three wheel base and one of the B reels is required when sounding with the 100 pound weight or when using one of the lighter weights where the distance from the bridge to the water surface is great. The type A crane mounted on a four wheel truck complete with counter weights and motor driven reels is available for use with the 100 and 150 pound weights. Information should be recorded in the Field Data Book to assist with the selection of equipment required.

Note:

The practice of using pound units when referring to sounding weights, will continue until such time as the Survey acquires sounding weights that have been designed in metric values. For convenience purposes the metric equivalents of the more commonly used Columbus weights are listed below.

15 lb. - 6.8 kg	75 lb. - 34.0 kg
30 lb. - 13.6 kg	100 lb. - 45.5 kg
50 lb. - 22.7 kg	150 lb. - 68.0 kg

With the equipment assembled, check the continuity of the current meter circuit by connecting the headphones or beeper. Note and record the size of weight used and the position of the meter above the bottom of the weight. Begin the measurement by recording the time, the edge of the stream (right or left) and the distance from the initial point to the water's edge.

The direction of flow is often not perpendicular to a bridge measuring section. Moreover it may be consistent throughout the section or it may change from vertical to vertical within the section and often vary with changes in stage. The cosine value can be measured easily by placing the left edge of the note paper along the bridge rail and viewing the wake from the suspension cable. This procedure is described in detail under "Correction for Angular (Oblique) Flow".

The current meter should be inspected frequently during the course of a discharge measurement. This is particularly important during high flow measurements when debris can foul the bucket wheel or during low flow periods when weed growth is encountered.

BOAT MEASUREMENTS

Boat measurements usually require not only a lengthy set-up time but also extra help to handle the boat and the transportation and maintenance of additional equipment. This method for obtaining discharge measurements is normally used only when cableways and bridges are not available. In other instances, even though bridges are available, they may not be suitable as structures to meter from.

The boat measurement method would also be used if a bridge or cableway section was blocked with debris or rendered unusable for some other reason. Boats often provide the only practicable means of obtaining measurements during floods or high water conditions.

There are several methods for positioning a boat to obtain soundings and determine velocities, but the following are the methods most commonly used by the Water Survey:

(1) Positioning is obtained using a tagline maintained on site.

(2) Positioning is obtained using a tagline strung prior to each measurement.

Stringing a Tagline

Tagline stringing is one operation that requires skill, coordination and caution by those involved. Not only are there potential hazards during this operation, but the fact that this is most often carried out at remote locations adds to the seriousness of any accident. TAKE CARE!

Aside from the small hand-held tagline used during wading measurements, two larger types of tagline used by the Survey have been placed across spans of up to 500 m. The permanent tagline is usually a heavier cable erected during the winter months when it can be hauled across the ice surface or pulled across with a large boat at the time construction is carried out at the station. Quite often this type of tagline can be raised and lowered to accommodate small boat traffic on the river.

The temporary tagline is strung for the duration of the discharge measurement and removed afterwards. Cables that range in diameter from 1.5. mm to 4.5 mm are used. This operation is normally carried out with the reel mounted on shore; however, it has on occasion been accomplished with the reel positioned in the boat. Do not secure the reel to the boat; in case of trouble, jettison the reel and cable immediately. The equipment can usually be retrieved afterwards.

The important feature in tagline stringing is to keep as much of the cable out of the water as is practicable. This not only reduces the amount of downstream drag on the cable but eliminates the possibility of snagging the cable on the stream bottom. The best way to achieve this is to position the reel high on the shore. It may not always be possible to locate a suitable, high bank for this purpose and a guide pulley may have to be attached to a tree or suspended from a tripod fashioned from trees cut in the vicinity to gain the height required.

The shore opposite the reel must be free of debris and boulders to permit the boat to be beached under power. An anchoring cable is fixed to a tree or deadman and carefully laid out to the shore. A cable gripper or a hook, depending on the hook-up method used, is fitted to the end of the anchoring cable.

The next step is to "run" the cable across the river. Three people are normally required for this operation. One person on shore, controls the reel and the rate at which the cable is payed out, another operates the boat and the third person anchors the boat if necessary when reaching the far shore, and completes the connection between the tagline and anchor cable.

When a larger diameter cable is being strung and the span is great, the tagline can be secured to the boat by rope. The rope should be fastened at a point approximately one-third of the boat length from the stern to enable the boatman to maintain steerage. An extra amount of cable should be coiled in the bottom of the boat. This portion of the cable is fed into a gripper or hook on the anchor cable when the other shore is reached. The third person must stand by with a sharp axe or knife and be ready to cut the rope in the event of an emergency.

Where spans are not too great and small diameter cable is used, the cable can be handheld during the crossing by way of a metal ring fitted to the end of the tagline. The tagline must be carefully payed out from the reel and the person holding the end of the cable in the boat must be prepared to drop the ring the moment any difficulty is encountered. The cable can be retrieved and another attempt made to get it across the river. When the opposite shore is reached, the ring is slipped onto the hook or gripper attached to the anchor cable. Where adequate preparations have been made, with the correct approach through technique and teamwork, the stringing of a tagline is not necessarily a chancy dash, but rather becomes a systematic operation. DO NOT attempt to get more distance above the water by standing in the boat.

Aside from the metering frames especially manufactured to fit the various types of boats used, the sounding and metering equipment required for a boat measurement is the same as that used for bridge and cableway measurements.

Boat Positioning by Targets and Instrument

(a) Transit Method. After a cross-section has been selected, erect two or more targets on an extension of the section line on one bank of the river. They must be positioned so that they can be readily seen and matched from any point on the cross-section, and be spaced a suitable distance apart so that accurate alignment of the boat can be achieved. On rivers with steep banks it may be necessary to erect a series of targets to accomplish this.

Select and chain a baseline either upstream or downstream from the cross-section. The length should be a distance equivalent to at least half that of the cross-section. Install a hub at the end of the baseline upstream or downstream from the cross-section. From this position the angles of intersection with the cross- section will be not less than 25°. A transit is set up at this location and is used to position the boat at selected points along the section.

The boat crew, with instructions from the instrument man and by sighting on the alignment targets, maneuvers the boat to the selected point on the cross-section. Communications between the instrument man and boat crew are usually by radio although prearranged hand signals can be used. It is often possible and indeed preferable to position the boat by steering and using the thrust of the motor to hold it, thus eliminating the need for the time consuming process of anchoring. This technique can also be used with the Pivot Method and in some instances with the Sextant Method.

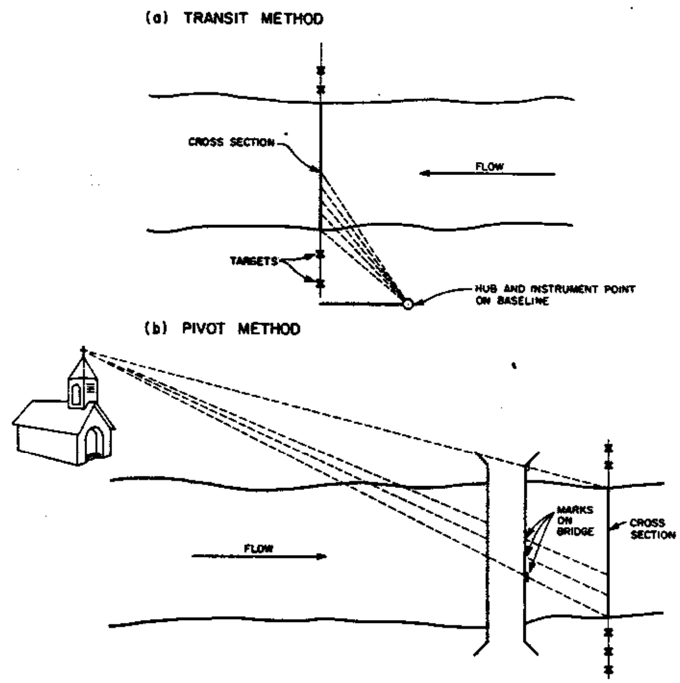


Figure 6

(b) Pivot Method. This method can be used with targets and a bridge or other structure that spans the river near the cross-section, or with a series of targets positioned on shore.

The cross-section alignment targets are installed in the same manner as was described for the transit method. Next select a pivot point on shore which may be located in front of or behind the structure spanning the river. It must be a sufficient distance from the structure so as not to emphasize any sighting error. Determine the width of the river at the cross-section by stadia, triangulation, chaining or electronically.

From the cross-section and at one shore, sight on the pivot target and the structure and mark the structure at this point. Repeat this process at the other shore. Now determine the number of measuring verticals required and divide and mark these distances on the structure accordingly.

During a discharge measurement the boat is kept on the cross-section by using the alignment targets on the shore and positioned for each vertical by sighting on the pivot target and the marked structure.

(c) Sextant Method. Section alignment targets and a baseline must be established in accordance with the instructions described in the transit method. Install a control target directly over the hub at the end of the baseline. The baseline must be of sufficient length to produce sextant angles greater than 25°, because the accuracy obtainable with this instrument at lesser values is greatly reduced. A set of targets should also be installed on the opposite shore to avoid the need to observe angles over short distances, another potential source for inaccuracy. Aim the control targets so that they face the mid-point of the cross-section and are readily seen from any point on the section. Although the control targets can be located either upstream or downstream from the cross-section, those positioned upstream usually offer the greatest convenience.

Determine the distance from the initial point to the water's edge by sighting on targets mounted on the far shore. Set the predetermined angle for the first observation vertical on the sextant and power the boat along the section. Check the progress of the boat with the sextant and, as the targets coincide, move the boat upstream and drop the anchor. The boat can then be allowed to drift back onto the cross-section. Obtain another observation with the sextant and record the reading. If this reading shows the position of the boat to be within a few feet of the predetermined position, proceed with the sounding and velocity observations. As the measurement progresses past the mid-point of the cross-section, sight on the other control and alignment targets until the measurement has been completed. By observing the targets from a greater distance, a higher order of accuracy can be achieved.

Table 2

Baseline is 1,000 feet long and perpendicular to the cross-section

Angle Measured With Sextant on Boat	Distance From Target at end of cross-section	Error of ±0°03' gives distance error of
63° 26' 06"	500 ft.	±1.1 ft.
45° 00' 00"	1000 ft.	±1.7 ft.
33° 41' 24"	1500 ft.	±2.8 ft.
26° 33' 54"	2000 ft.	±4.4 ft.
21° 48' 05"	2500 ft.	±6.3 ft.
19° 01' 32"	2900 ft.	±8.2 ft.

For other baseline lengths the error is proportional, i.e., for a baseline of 100 feet and an angle of 19° 01' 32" the error would be 0.8 ft.

Table 3

Baseline is 1,000 feet long and perpendicular to the cross-section

Angle Measured With Sextant on Boat	Distance From Target at end of Baseline	Error of ±0°03' gives distance error of
95° 00'	472 ft.	±0.7 ft.
85° 00'	618 ft.	±0.7 ft.
75° 00'	769 ft.	±0.8 ft.
65° 00'	936 ft.	±0.9 ft.
55° 00'	1132 ft.	±1.1 ft.
45° 00'	1383 ft.	±1.6 ft.
35° 00'	1742 ft.	±2.2 ft.
25° 00'	2343 ft.	±4.1 ft.
20° 00'	2849 ft.	±6.2 ft.

Use of the Sextant. Tables 2 and 3 show the results of some field tests and indicate the accuracies that can be expected when using a sextant to position a boat. Different people reading a set angle on the particular sextant that was used obtained a wide variety of answers because of the parallax between the sextant vernier scale and its index marker. The largest difference recorded was approximately 0°03'. For the calculations in Tables 3 and 4 a setting and reading error of ±0°03' was used. A field test conducted by two persons over a triangular course indicated that a combined reading and setting error is not likely to exceed 03' even under poor conditions. It can be seen from Tables 3 and 4 that sextant angles should be greater than 25°.

MEASUREMENT UNDER ICE CONDITIONS

The careful selection of a winter metering section is as important as that for an open-water section. Although it is not always possible, try to locate a section that will have reasonable access. The savings in time and effort expended during the winter months will make this well worthwhile. Prior to freeze-up, investigate channel and flow conditions at more than one site. At a later date, should conditions prove unfavourable at one location, then one or more others are available for which there is some background information. Poor ice cover, slush ice accumulation or difficult accessibility are a few reasons why an otherwise good section may have to be abandoned.

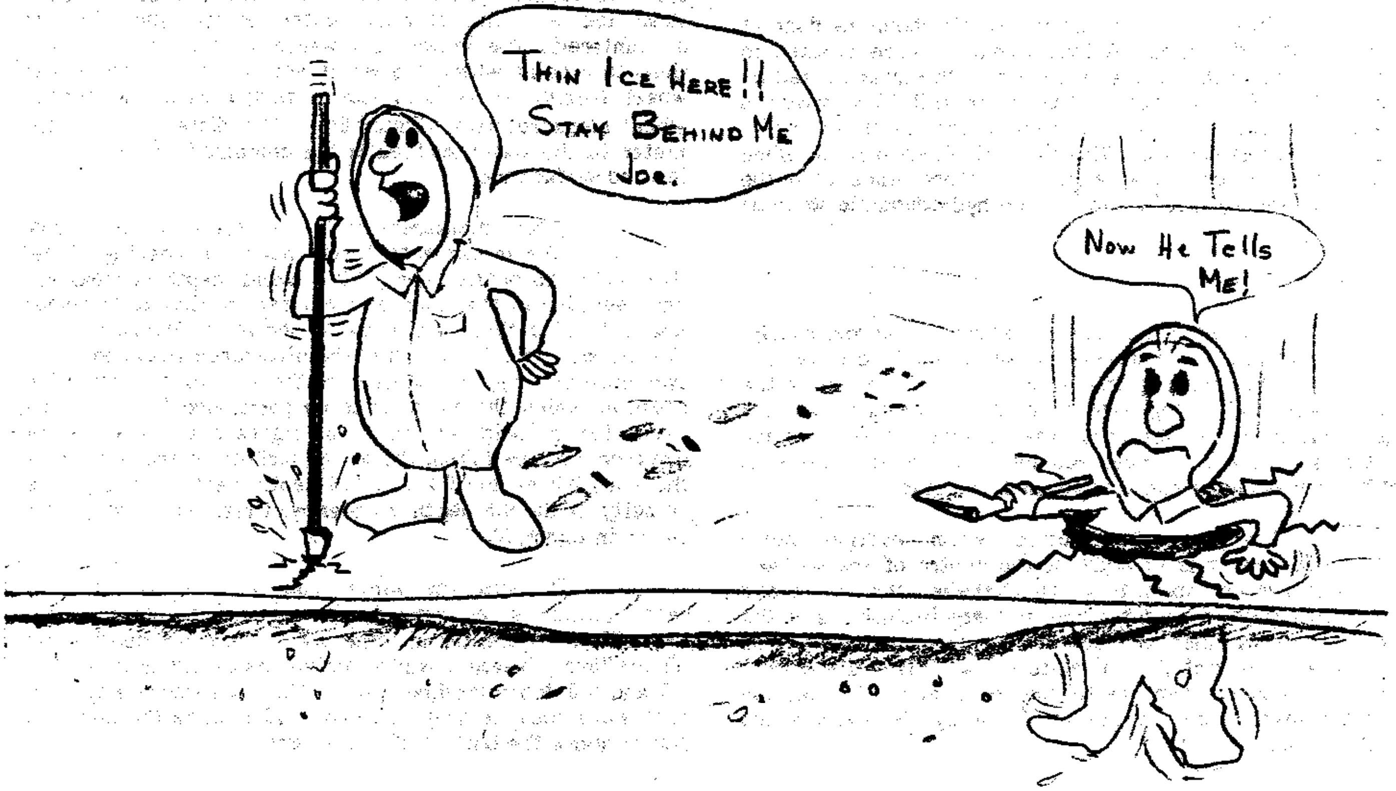
When selecting a site look for a relatively straight reach of river where the water will remain in one channel and where the channel is well defined. A section with good distribution of velocities is desirable since these will often remain good after the formation of ice cover. Avoid reaches below sections that have traditionally remained ice-free during the winter months. Heavy concentration of slush ice will often form in these locations. These conditions can add significantly to the complexity and difficulty of making a winter measurement.

On the other hand, open-water sections on rivers that can be waded will often provided very good winter metering locations with the removal of a minimal amount of ice, usually along either shore. Take care to locate the metering section well downstream from the surface ice cover to avoid surface velocity disturbances. If ice has to be removed from the metering section, allow adequate time for conditions to stabilize before starting a measurement. The ice will often jam in the channels and create an additional but likely temporary backwater condition.

Ice Safety

Common sense must be exercised when walking across an ice-covered stream. Since the ice is subject to continuing change, it must be carefully tested before any measurement is attempted. A fresh fall of snow will often cover areas that would otherwise be recognized as hazardous.

The best method for testing the safety of ice cover is to use an ice chisel. The ice should be struck a solid blow every few paces as the section is crossed. If there is any doubt about the safety of the ice, take the time to check it thoroughly. If there are open sections of water close to the measuring site or if the chisel penetrates the surface easily, the cross-section should be abandoned and another cross-section tested. A MEASUREMENT MUST NEVER BE ATTEMPTED AT THE RISK OF THE FIELD OFFICER'S LIFE.



The following table is taken from "Suspect" Safety Bits and Pieces, Information Branch, Safety Programme Development Section, Ministry of Natural Resources, Ontario, February 1975.

Ice Thickness inches	Ice Thickness centimetres	Permissible Load
Less than 2	Less than 5.1	not safe
2	5.1	one person on foot
3	7.6	group in single file
7.5	19	2-ton truck (car, snowmobile)
8	20	2.5-ton truck
10	25	3.5-ton truck
12	30	8-ton truck

This table applies to clear, blue lake ice only. River ice is weaker than clear lake ice and slush ice is only half as strong. Repeated travel over the same ice weakens it.

Although this table lists some safe load-bearing capacities for ice cover, it must be recognized that there are certain risks involved when crossing ice-covered rivers and lakes, particularly if the crossing is made by vehicle.

Fluctuating water levels will cause unsafe conditions. A drop in water level will create "ice bridging", ice will remain attached to the shore but be unsupported by water. A rise in water level will cause overflooding and one or more layers of relatively thin ice will form.

Travel on ice cover by vehicle should be done at greatly reduced speeds. A hydrodynamic wave created in the water beneath the ice, together with stress caused by the vehicle itself, can cause the ice to fail. The stress is greatest when, among other things, the depth of water under the ice is shallow. This is particularly critical when approaching or travelling close to a shore since then the ice is stressed by a reflection of the hydrodynamic wave as well.

Measurement Procedures

It is often possible to determine approximately, the shape of the winter measuring section at the time it is being evaluated prior to freeze-up. A simple sketch in the Field Data Book along with notes on flow conditions are very helpful when selecting the spacing of observation verticals for the first measurement. Winter measurements from previous years can also be used as a guide.

The general practice when cutting holes through ice cover is to start at the centre of the section. One or two more exploratory holes between the centre and either shore will help determine if there is slush ice at the section and whether or not the measurement should be attempted at one of the alternate sites. This will also help avoid unnecessary damage to the ice auger. The section with the least amount of slush is normally the one selected for the measurement.

The holes across the metering section should be distributed so that the discharge measured in any one panel is no greater than approximately 5 percent of the total. (See Discharge Measurements, General Metering Criteria). Where it was not possible to select and assess the metering section before the ice cover was formed, first determine where the edge of water is at both shores. Then cut a number of evenly spaced holes. A few trial observations will indicate where the greatest depths and velocities are located. Additional holes can then be cut to ensure the proper spacing between verticals.

Discharge measurements through ice cover can be made using various equipment assemblies. The most commonly used are the winter rod set and the winter metering sled. Hand lines have been used at locations where access to a station is difficult and the depths at the metering section are too great for the winter rod set. Various sounding weights that will pass through the 8-inch holes (no metric equivalent as yet available) cut with the ice auger are available for use with either the metering sled or the hand line.

For measurements from ice cover it is necessary to determine the effective depth, that is, the distance between the bottom of the ice surface or slush ice pack and the bottom of the stream. This is illustrated in Figure 7.

To begin a measurement, the first step at a selected vertical is to measure the distance from the water surface to the bottom of the ice. A measuring scale as illustrated in Figure 8a is used for this purpose. If using the rod set, the top protrusion on the base and the graduation on the rod can be used instead (Figure 8b). In order to define the ice horizon (the interface between the slush ice and the flowing water where slush ice is encountered), the meter is lowered through the ice and slush to a point where the water velocity turns the bucket wheel freely. It is then slowly raised until the bucket wheel stops rotating (Figure 8c). The distance from the meter to the water surface is the combined depth of slush ice and surface ice.

This measurement is entered in the third column of the meter note form under the heading "Total depth/W.S. to bottom ice". The overall depth is measured and recorded in the same column, except that it is placed above the ice thickness value as shown in Figure 9 or 10. The effective depth, which is the difference between these two observations, is entered in the fourth column. The depth at which the meter is to be positioned for observing velocities is computed from this figure and added to the distance measured from the water surface to the bottom of the ice. Where the 0.2 and 0.8 depth method is used, the velocity at the 0.8 depth is observed first. These steps are shown in Figure 10.

If using the winter rod set, the 0.2 and 0.8 depth method is recommended where the effective depths are 0.75 m or greater and the 0.5 method for depths less than 0.75 m. Where a winter weight assembly is used, the 0.2 and 0.8 depth method can only be used where effective depths are equal to or greater than 1.3 m since the meter is 0.24 m above the bottom of the weight.

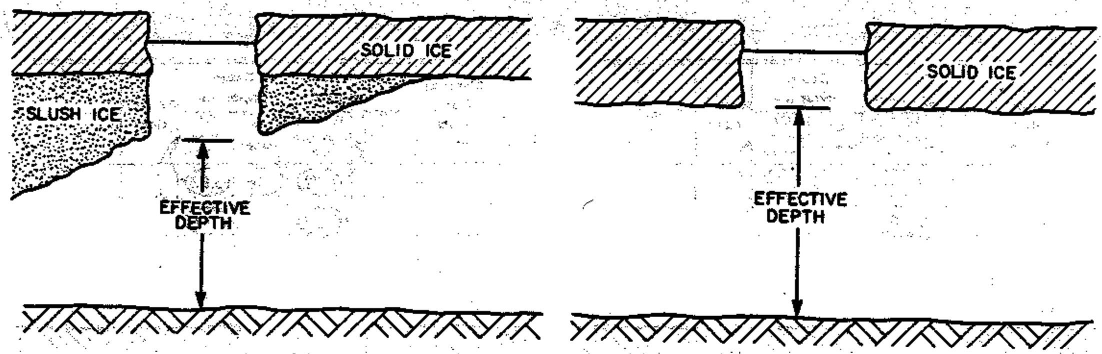


Figure 7

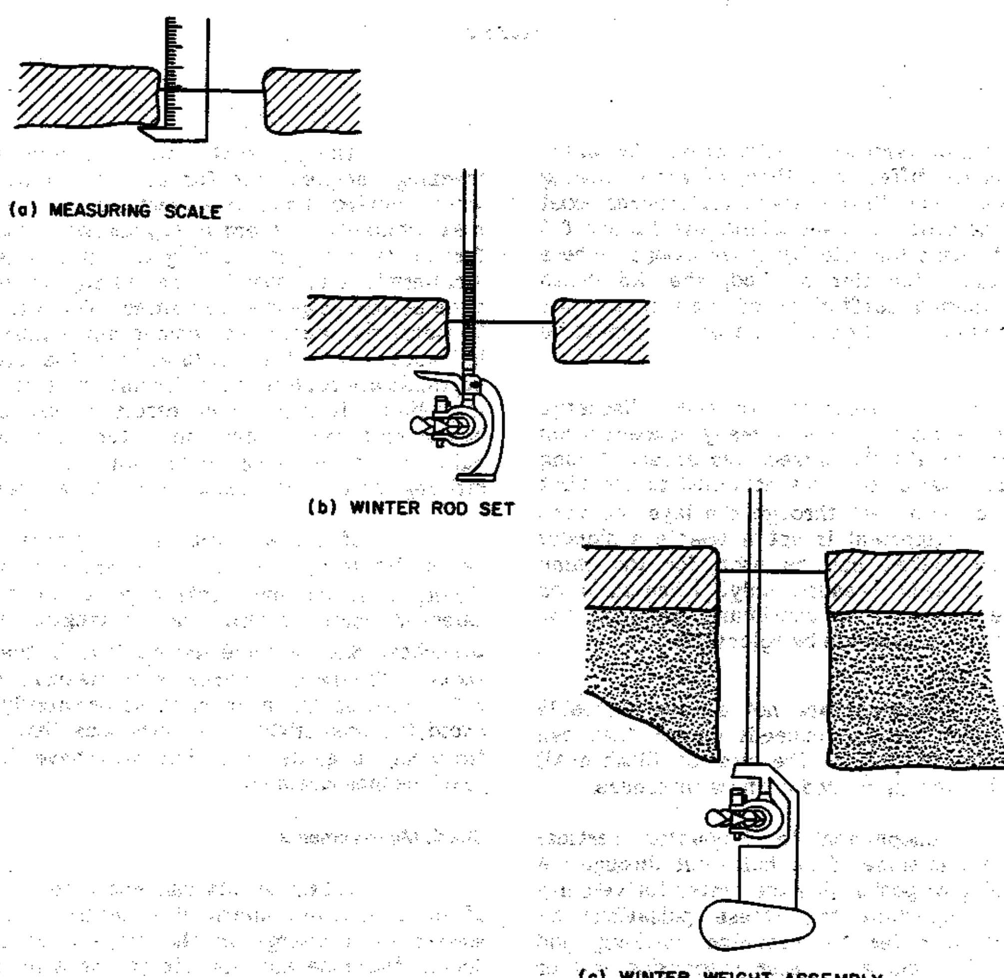


Figure 8

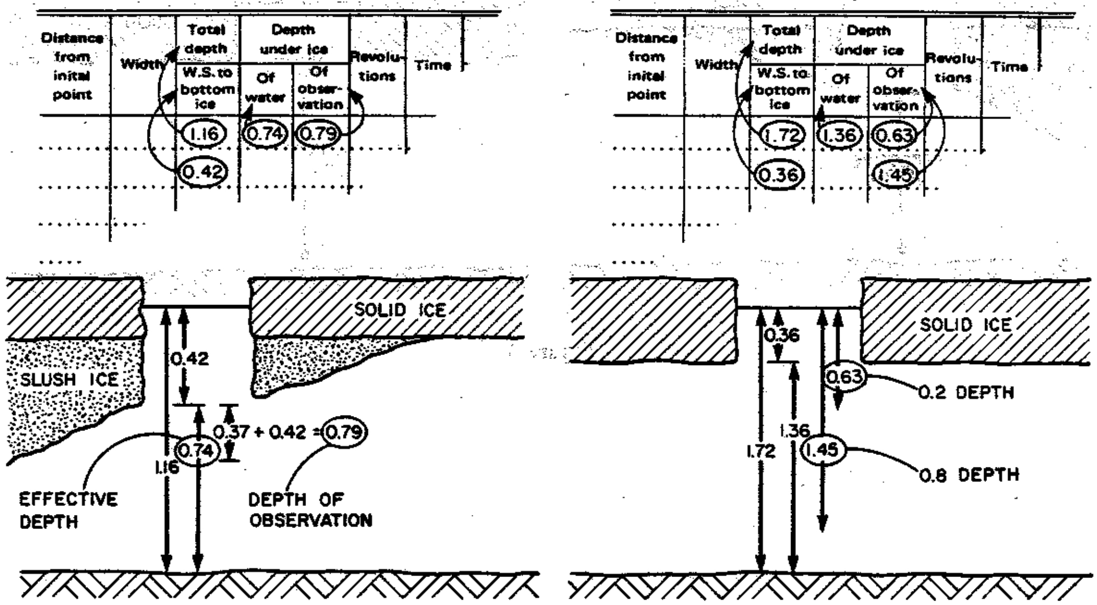


Figure 9

The shapes of vertical velocity curves for water flowing under ice cover differ from those of water flowing in an open channel. Even though these differences exist and provided that the depths are sufficient, the 0.2 and 0.8 depth method can be used for velocity observations. Where depths are insufficient for this method, the 0.5 depth method with an assumed coefficient of 0.88 or the 0.6 depth method with an assumed coefficient of 0.92, must be used.

At times it is necessary to make discharge measurements at locations that have a heavy concentration of slush ice lodged beneath the surface ice cover. A long aluminum pole with a series of disks attached to the first section is used to clear a path through the layer of slush ice. If this piece of equipment is not available a slender tree that has been limbed can be used for the same purpose. These are interim measures only. When slush ice concentrations are a known or continuing problem, the metering section should if possible be relocated.

Slush ice conditions are not always avoidable and at times the slush horizon exceeds depths that can readily be cleared with poles. The use of Slush-n-All weight assemblies are recommended in these instances.

It is not uncommon to encounter vertical pulsation of the water in some of the holes cut through ice cover. When sounding or positioning the meter for velocity observations it is important that these pulsations be carefully averaged in order to minimize sounding and positioning errors. The current meter suspension rod or cable should be held as close to the upstream side of the hole as possible in order to reduce any effect the pulsations might have on the meter should it be positioned close to the water-ice interface.

The current meter should be exposed to freezing temperatures for as short a period as possible when moving from one vertical to the next during a measurement. If there is any question that ice may have formed on the meter during the time it is exposed to the air, permit it to "soak" in the moving water for a period of time before observing velocities. This will allow the water to warm the meter and remove any minor build-up of ice. In cases where temperatures and the distances between verticals are such that ice formation on the meter becomes a problem, it may be necessary to use a small portable heater or torch to keep the meter ice free. Excessive ice build-up on metering rods can be simply removed by striking the ice with a small wrench or screw driver.

If the selected metering section has proven to be satisfactory, the time required for locating verticals during later measurements may be saved by marking the selected verticals with 1 metre lengths of stick or tree branches. Simply place the markers in the holes and allow them to freeze in. During later measurements, drill holes a few feet upstream from those previously used. This will avoid the possibility of disturbances that could be caused from any irregular ice that may have formed after the previous measurement.

Check Measurements

Certain events can and often do produce results of an unusual and unexpected nature. These in turn may appear as a change in the stage-discharge relationship. Should there be any uncertainty or a departure from the existing relationship when the results of a measurement are plotted on the field curve, a check measurement must be obtained. (See Figure 12). If at all possible, use a different current meter when obtaining the check

SAMPLE WINTER METER NOTES
0.5 METHOD

.0 .10 .20 .30 .40 .50 .60 .70 .75 .80 .85 .90

Station

Distance from inital point	Width	Total depth: W.S. to bottom ice	Depth under ice: Of water	Depth under ice: Of observation	Revolutions	Time	Velocity: At point	Velocity: Mean	Area	Discharge
0		0	R	edge	at	10:30				
20		(1.16)								
		(0.42)								

Step 1
Water surface to bottom of ice

Step 2
Water surface to stream bed

.0 .10 .20 .30 .40 .50 .60 .70 .75 .80 .85 .90

Station

Distance from inital point	Width	Total depth: W.S. to bottom ice	Depth under ice: Of water	Depth under ice: Of observation	Revolutions	Time	Velocity: At point	Velocity: Mean	Area	Discharge
0		0	R	edge	at	10:30				
20		1.16	(0.74)	(0.79)						
		0.42								

Step 3
Effective depth

Step 4
Depth of observation (water surface to bottom of ice plus 0.5 of effective depth)

.0 .10 .20 .30 .40 .50 .60 .70 .75 .80 .85 .90 .92

Station

Distance from inital point	Width	Total depth: W.S. to bottom ice	Depth under ice: Of water	Depth under ice: Of observation	Revolutions	Time	Velocity: At point	Velocity: Mean	Area	Discharge
0	10	0	R	edge	at	10:30				
20	20	1.16	0.74	0.79	(20)	(45)	(0.306) (88)	(0.269)	14.8	3.98
		0.42								
40										
60										

Step 5
Observe and record revolutions and time

corrected velocity

coefficient for 0.5 depth observation

from current meter rating table

Figure 10

0.2 and 0.8 METHOD

.0 .10 .20 .30 .40 .50 .60 .70 .75 .80

Station

Distance from inital point	Width	Total depth W.S. to bottom ice	Depth under ice Of water	Depth under ice Of observation	Revolutions	Time	Velocity At point	Velocity Mean	Area	Discharge
0	10	0	R	edge	at	10:30				
20	20	1.16	0.74	0.79	20	45	0.306 / 88	0.269	14.8	3.98
		0.42								
40	20	1.72								
		0.36								
60										

.85 .90 .92 .94

Step 1
Water surface to bottom of ice

Step 2
Water surface to stream bed

.0 .10 .20 .30 .40 .50 .60 .70 .75 .80

Station

Distance from inital point	Width	Total depth W.S. to bottom ice	Depth under ice Of water	Depth under ice Of observation	Revolutions	Time	Velocity At point	Velocity Mean	Area	Discharge
0	10	0	R	edge	at	10:30				
20	20	1.16	0.74	0.79	20	45	0.306 / 88	0.269	14.8	3.98
		0.42								
40	20	1.72	1.36	0.63						
		0.36		1.45						
60										

.85 .90 .92 .94

Step 3
Effective depth

Step 4
Depths of observation
Water surface to bottom of ice
plus (1) —0.8 effective depth
(2)—0.2 effective depth

.0 .10 .20 .30 .40 .50 .60 .70 .75 .80

Station

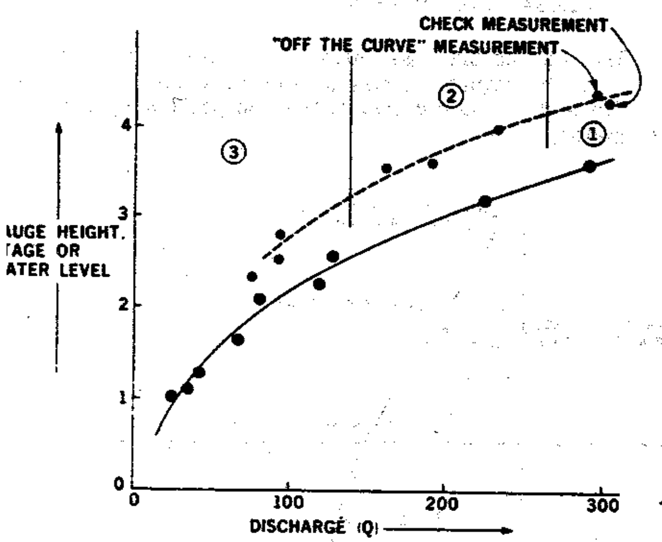
Distance from inital point	Width	Total depth W.S. to bottom ice	Depth under ice Of water	Depth under ice Of observation	Revolutions	Time	Velocity At point	Velocity Mean	Area	Discharge
0	10	0	R	edge	at	10:30				
20	20	1.16	0.74	0.79	20	45	0.306 / 88	0.269	14.8	3.98
		0.42								
40	20	1.72	1.36	0.63	30	48	0.428	0.357	27.2	9.71
		0.36		1.45	20	45	0.306			

.85 .90 .92 .94

Step 5
Observe and record velocities
(1) —0.8 depth
(2) —0.2 depth

Figure 11

measurement to reduce the possibility of introducing a systematic error. Obvious damage such as a bent shaft, bucket wheel hub, dented buckets and bent bucket wheel can be spotted readily by visual inspection. Other problems which can affect the operation of a meter are worn bearing surfaces or a worn or damaged pivot point. These latter problems are often not readily detectable and can be found only after close inspection. The care, adjustment and operation of the Price Current Meter is described in detail in the section on Instruments, Equipment and Equipment Assemblies.



1. Check measurement to verify results of the "off the curve" measurement.

2. Define changes in this range next.

3. Define the lower range. It is quite common, particularly for smaller streams, for the duration of flow in the medium and high ranges of the stage-discharge relationship to be short. This must be kept in mind when evidence of a change in the relationship has occurred so as not to have large sections of the curve undefined. In the lower range, the rate of change decreases and thus more time is available to define this portion of the curve.

Figure 12

NEVER attempt to adjust a current meter that has been used during a suspect measurement. The meter should be returned for an "as received" calibration, before repair and servicing.

This is by no means the only reason for obtaining a check measurement. Having measured a very high flow, particularly one which is beyond previous measurements on the existing curve, it is good practice to obtain another measurement to corroborate the results of the first. If it seems likely that the stage will change rapidly, it may well be necessary to remain at the station and meter the flow at regular intervals throughout the rise and fall so as to define any change in the stage-discharge curve. If a manual gauge is being used at the site, an appropriate number of gauge readings must be obtained as well. Quite often, a period of high flow can significantly change the previously defined stage-discharge relationship.

SPECIAL TECHNIQUES

Sounding

Downstream drag on the sounding line, current meter and weight assembly makes it difficult to sound and position the meter accurately. Sounding from a great height above the water surface, using a weight that is too light, or working under conditions of high velocities and large depths, are all factors which individually or in any combination will contribute to sounding and positioning errors.

Sounding observations should be made when the weight first comes in contact with the river or stream bed. Increased velocities around the sounding weight will cause scouring of unstable material if the weight is allowed to rest on the stream bed for any length of time.

There are times when the heaviest weight readily available will be insufficient to prevent the metering assembly from being deflected downstream a slight amount. A simple method to reduce downstream drag is to remove the current meter and complete the soundings with the weight only. Often this is all that is required to obtain reasonably accurate depths. Once the depths have been determined, replace the current meter and proceed with the measurement. It may be necessary to use one of the procedures discussed in "Measuring High Velocities" to complete the measurement.

Some rivers have inherently stable channels. At these locations standard soundings obtained at stages when conditions are more ideal for sounding, can be used to determine the required depths during a discharge measurement.

TAGGING THE SOUNDING CABLE

Rather than using the method just described for correcting observed depths, the actual depth can be determined by using index streamers attached to the sounding cable. Fit a series of short streamers to the cable at convenient intervals above the current meter or the bottom of the weight. The streamers can be colour coded for easy identification. They can be attached by tape or by lifting two or three strands of the sounding cable enough to clamp the streamer between the strands.

During sounding operations, after the weight touches the stream bed, the assembly is raised until the nearest streamer reaches the water surface. The distance required to raise the tag to the surface is added to the known distance of the tag above the meter or bottom of the weight. This method can also be used when positioning the meter for velocity observations.

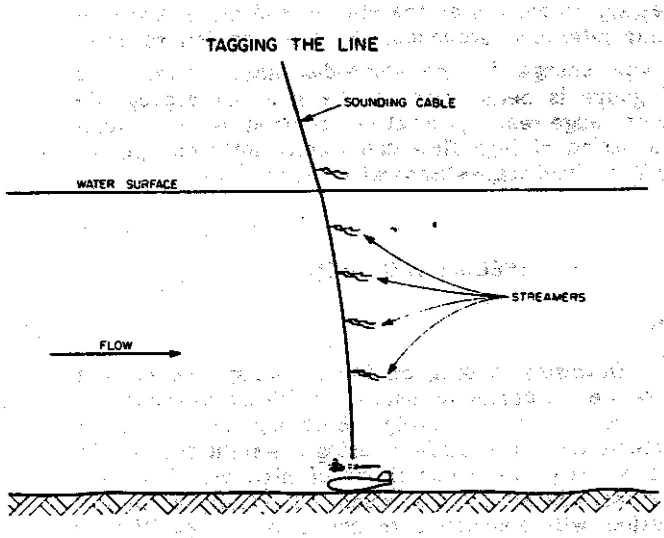


Figure 13

It can be seen from Table 5 that if the distance to the water surface is not too great and the change in the vertical angle of the cable is minor when the sounding line is raised to determine the distance to the first streamer, the sounding error will be minor.

COMPUTED DEPTH CORRECTION METHOD

The metering crane or cable car must be fitted with a protractor to determine the angle of drag and hence the correction required for over-sounding. The procedure is as follows and is illustrated with an example:

1. Measure and record the distance from the protractor to the water surface.

2. Obtain and record the sounding.

3. Observe and record the vertical angle of the suspension cable at the protractor when the metering assembly is submerged.

4. Obtain dry-line correction, from Table 5, and apply to sounded depth.
   Dry-line correction - distance from protractor to water surfaee versus vertical angle of sounding line).

5. Read wet-line correction from Table 6 and apply to dry-line corrected depth.

6. Raise the meter to 0.8 of the vertical depth and record the velocity observation.

7. Raise the meter to the 0.2 vertical depth position and record the velocity.

The following example illustrates this procedure when applied to a discharge measurement: See Figure 15.

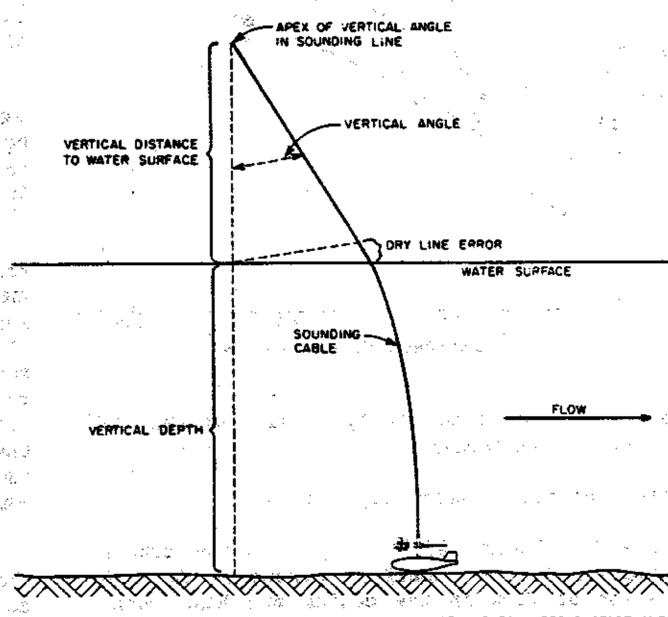
1. The distance from the bridge crane (protractor) to the water surface is recorded at the top of the note sheet.

2. The depth sounded at section 40 is 11.70 m and the observed vertical angle of the sounding cable is 16°. (Angle is observed with the weight at the stream bed but fully supported by the cable.)

3. The dry-line correction for 21.34 m at an angle of 16° is taken from Table 5 and applied to the sounding, 11.70 - 0.86 = 10.84.

4. The correction for the wet-line depth of 10.84 m is obtained from Table 6. The corrected depth is now 10.84 - 0.14 = 10.70 m.

5. The 0.2 and 0.8 observation depths are computed from this figure. It may also be necessary to use dry and wet-line corrections when positioning the meter.



DRY LINE CORRECTION - DIFFERENCE BETWEEN VERTICAL DISTANCE TO WATER SURFACE AND THE OBSERVED DISTANCE

WET LINE CORRECTION - DIFFERENCE BETWEEN THE VERTICAL DISTANCE FROM THE WATER SURFACE TO THE STREAM BED AND THE OBSERVED DISTANCE

Figure 14

Angle of Flow Correction

A correction must be applied to the observed velocity if the angle of the current is not perpendicular to the measuring section. The correction is the cosine of the angle observed at the metering point. Cosine values for various angles have been computed and printed along the top, bottom and right side of the Hydrometric Survey Note form, to permit a "quick and easy" application of the required correction value. See following illustration.

In practice, the angle of flow is observed from the wake of the wading rod or suspension cable. If it is difficult to see the wake from a bridge or cable car the meter can be used to indicate the angle by positioning it at or just below the water surface. The left edge of the note page is held parallel to the tagline, cable car or bridge.

.0 .10 .20 .30 .40 .50 .60 .70 .75

Station .80

← Figure 15

Distance from initial point	Width	Total depth W.S. to bottom ice	Depth under ice: Of water	Depth under ice: Of observation	Revolutions	Time	Velocity: At point	Velocity: Mean	Area	Discharge	
											.85
	L.B.	at 14:05			21.34m to water surface						
10	5	3.86		2.32	100	43^{-}		1.579	19.3	30.5	.90
20	10	5.24		1.04	150	51^{5}	1.977	1.807	51.8	93.6	.92
(4°)		−0.06 A 5.18		4.14	100	41^{5}	1.637				.94
30	10	9.84		1.85	200	46^{5}	2.797	2.180	92.7	202.1	.96
(12°)		−0.50 A 9.34 −.07 W 9.27		7.42	100	43^{5}	1.562				.97 .98
40	10	11.70		2.14	200	46^{5}	2.918	2.438	107.0	260.9	.99
(16°)		−0.86 A 10.84 −0.14 W 10.70		8.56	150	52^{-}	1.958				
50	10	12.62		2.21	200	42^{-}	3.229	2.906	110.6	321.4	1.00
(19°)		−1.35 A 11.27 −0.21 W 11.06		8.85	200	52^{5}	2.584				
E.P. 60	5	10.66 e		3/4 vel	@	50		2.180	53.3	116.2	.99
pier											.98
											.97
											.96
											.94
											.92
											.90
											.85
											.80

EXAMPLE

.0 .10 .20 .30 .40 .50 .60 .70 .75

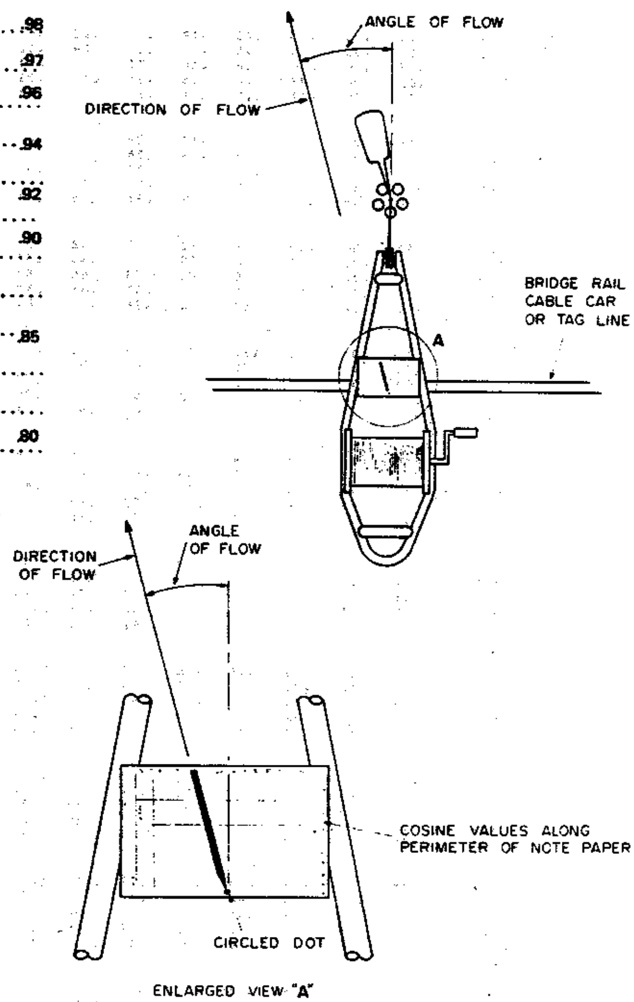


Figure 16 →

ANGLE OF FLOW CORRECTION

Place one end of a pencil over the circled dot at the left edge of the paper and move the other end until the pencil is parallel with the indicated angle of flow. Read and record the angle of flow cosine value as illustrated in Figure 16.

Cableways are usually located carefully so as to avoid sections with angular flow. Since angular flow at some metering sites varies with changes in water level, the need to apply coefficients at some of the observation verticals will similarly vary with the stage.

Angular flows are frequently encountered at bridge measurement sections since bridge sites are selected primarily for purposes other than stream gauging. It is quite often possible to determine and apply one cosine correction value to the entire discharge rather than to apply individual corrections. This should be verified over a period of time and after a number of measurements have been obtained.

Table 5

AIR-CORRECTION TABLE, GIVEN DIFFERENCE IN METRES, BETWEEN VERTICAL LENGTH AND SLANT LENGTH OF SOUNDING LINE ABOVE WATER LINE FOR VERTICAL ANGLES 4-36 DEGREES

VERTICAL LENGTH (METRE)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	VERTICAL LENGTH (METRE)
3.0	.01	.02	.03	.05	.07	.09	.12	.15	.19	.24	.28	.34	.40	.46	.54	.62	.71	3.0
3.5	.01	.02	.03	.05	.08	.11	.14	.18	.22	.27	.33	.39	.46	.54	.63	.72	.83	3.5
4.0	.01	.02	.04	.06	.09	.12	.16	.21	.26	.31	.38	.45	.53	.62	.72	.82	.94	4.0
4.5	.01	.02	.04	.07	.10	.14	.18	.23	.29	.35	.43	.51	.60	.70	.81	.93	1.06	4.5
5.0	.01	.03	.05	.08	.11	.15	.20	.26	.32	.39	.47	.56	.66	.77	.90	1.33	1.19	5.0
5.5	.01	.03	.05	.08	.12	.17	.22	.28	.35	.43	.52	.62	.73	.85	.99	1.13	1.30	5.5
6.0	.01	.03	.06	.09	.13	.18	.24	.31	.39	.47	.57	.68	.80	.93	1.08	1.24	1.42	6.0
6.5	.02	.04	.06	.10	.14	.20	.26	.33	.42	.51	.61	.73	.86	1.01	1.16	1.34	1.53	6.5
7.0	.02	.04	.07	.11	.16	.21	.28	.36	.45	.55	.66	.79	.93	1.08	1.25	1.44	1.65	7.0
7.5	.02	.04	.07	.12	.17	.23	.30	.39	.48	.59	.71	.84	.99	1.16	1.34	1.55	1.77	7.5
8.0	.02	.04	.08	.12	.18	.24	.32	.41	.51	.63	.76	.90	1.06	1.24	1.43	1.65	1.59	8.0
8.5	.02	.05	.08	.13	.19	.26	.34	.44	.55	.67	.80	.96	1.13	1.31	1.52	1.75	2.01	8.5
9.0	.02	.05	.09	.14	.20	.28	.36	.46	.58	.71	.85	1.01	1.19	1.39	1.61	1.86	2.12	9.0
9.5	.02	.05	.09	.15	.21	.29	.38	.49	.61	.75	.90	1.07	1.26	1.47	1.70	1.96	2.24	9.5
10.0	.02	.06	.10	.15	.22	.31	.40	.52	.64	.79	.95	1.13	1.33	1.55	1.79	2.06	2.36	10.0
10.5	.03	.06	.10	.16	.23	.32	.42	.54	.67	.82	.99	1.18	1.39	1.62	1.88	2.17	2.48	10.5
11.0	.03	.06	.11	.17	.25	.34	.44	.57	.71	.86	1.04	1.24	1.46	1.70	1.97	2.27	2.60	11.0
11.5	.03	.06	.11	.18	.26	.35	.46	.59	.74	.90	1.09	1.29	1.52	1.78	2.06	2.37	2.72	11.5
12.0	.03	.07	.12	.18	.27	.37	.48	.62	.77	.94	1.14	1.35	1.59	1.86	2.15	2.47	2.83	12.0
12.5	.03	.07	.12	.19	.28	.38	.50	.64	.80	.98	1.18	1.41	1.66	1.93	2.24	2.58	2.95	12.5
13.0	.03	.07	.13	.20	.29	.40	.52	.67	.83	1.02	1.23	1.46	1.72	2.01	2.33	2.68	3.07	13.0
13.5	.03	.07	.13	.21	.30	.41	.54	.73	.87	1.06	1.28	1.52	1.79	2.09	2.42	2.78	3.19	13.5
14.0	.03	.08	.14	.22	.31	.43	.56	.72	.90	1.10	1.32	1.58	1.86	2.17	2.51	2.89	3.31	14.0
14.5	.03	.08	.14	.22	.32	.44	.58	.75	.93	1.14	1.37	1.63	1.92	2.24	2.60	2.99	3.42	14.5
15.0	.04	.08	.15	.23	.33	.46	.60	.77	.96	1.18	1.42	1.69	1.99	2.32	2.69	3.09	3.54	15.0
15.5	.04	.09	.15	.24	.35	.47	.62	.80	1.00	1.22	1.47	1.75	2.06	2.40	2.78	3.20	3.66	15.5
16.0	.04	.09	.16	.25	.36	.49	.64	.82	1.03	1.26	1.51	1.80	2.12	2.48	2.87	3.30	3.78	16.0
16.5	.04	.09	.16	.25	.37	.50	.66	.85	1.06	1.30	1.56	1.86	2.19	2.55	2.96	3.40	3.90	16.5
17.0	.04	.09	.17	.26	.38	.52	.69	.88	1.09	1.33	1.61	1.91	2.25	2.63	3.05	3.51	4.01	17.0
17.5	.04	.10	.17	.27	.39	.54	.71	.90	1.12	1.37	1.66	1.97	2.32	2.71	3.14	3.61	4.13	17.5
18.0	.04	.10	.18	.28	.40	.55	.73	.93	1.16	1.41	1.70	2.03	2.39	2.79	3.23	3.71	4.25	18.0
18.5	.04	.10	.18	.29	.41	.57	.75	.95	1.19	1.45	1.75	2.08	2.45	2.85	3.32	3.81	4.37	18.5
19.0	.05	.10	.19	.29	.42	.58	.77	.98	1.22	1.49	1.80	2.14	2.52	2.94	3.40	3.92	4.49	19.0
19.5	.05	.11	.19	.30	.43	.60	.79	1.00	1.25	1.53	1.84	2.20	2.59	3.02	3.49	4.02	4.60	19.5
20.0	.05	.11	.20	.31	.45	.61	.81	1.03	1.28	1.57	1.89	2.25	2.65	3.09	3.58	4.12	4.72	20.0
20.5	.05	.11	.20	.32	.46	.63	.83	1.06	1.32	1.61	1.94	2.31	2.72	3.17	3.67	4.23	4.84	20.5
21.0	.05	.12	.21	.32	.47	.64	.85	1.08	1.35	1.65	1.99	2.36	2.78	3.25	3.76	4.33	4.96	21.0
21.5	.05	.12	.21	.33	.48	.66	.87	1.11	1.38	1.69	2.03	2.42	2.85	3.33	3.85	4.43	5.08	21.5
22.0	.05	.12	.22	.34	.49	.67	.89	1.13	1.41	1.73	2.09	2.48	2.92	3.40	3.94	4.54	5.19	22.0
22.5	.05	.12	.22	.35	.50	.69	.91	1.16	1.44	1.77	2.13	2.53	2.98	3.48	4.03	4.64	5.31	22.5
23.0	.05	.13	.23	.35	.51	.70	.93	1.18	1.48	1.81	2.18	2.59	3.05	3.56	4.12	4.74	5.43	23.0
23.5	.06	.13	.23	.36	.52	.72	.95	1.21	1.51	1.84	2.22	2.65	3.12	3.64	4.21	4.85	5.55	23.5
24.0	.06	.13	.24	.37	.54	.73	.97	1.24	1.54	1.88	2.27	2.70	3.18	3.71	4.30	4.95	5.67	24.0
24.5	.06	.13	.24	.38	.55	.75	.99	1.26	1.57	1.92	2.32	2.76	3.25	3.79	4.39	5.05	5.78	24.5
25.0	.06	.14	.25	.39	.56	.77	1.01	1.29	1.61	1.96	2.37	2.82	3.32	3.87	4.48	5.16	5.90	25.0
25.5	.06	.14	.25	.39	.57	.78	1.03	1.31	1.64	2.00	2.41	2.87	3.38	3.94	4.57	5.26	6.02	25.5
26.0	.06	.14	.25	.40	.58	.80	1.05	1.34	1.67	2.04	2.46	2.93	3.45	4.02	4.66	5.36	6.14	26.0
26.5	.06	.15	.26	.41	.59	.81	1.07	1.36	1.70	2.08	2.51	2.98	3.51	4.10	4.75	5.46	6.26	26.5
27.0	.06	.15	.26	.42	.60	.83	1.09	1.39	1.73	2.12	2.55	3.04	3.58	4.18	4.84	5.57	6.37	27.0
27.5	.07	.15	.27	.42	.61	.84	1.11	1.42	1.77	2.16	2.60	3.10	3.65	4.25	4.93	5.67	6.49	27.5
28.0	.07	.15	.27	.43	.62	.85	1.13	[illegible]	1.80	2.20	2.65	3.15	3.71	4.33	5.02	5.77	6.61	28.0
28.5	.07	.16	.28	.44	.64	.87	1.15	1.47	1.83	2.24	2.70	3.21	3.78	4.41	5.11	5.88	6.73	28.5
29.0	.07	.16	.28	.45	.65	.89	1.17	1.49	1.86	2.28	2.74	3.27	3.85	4.49	5.20	5.99	6.85	29.0
29.5	.07	.16	.29	.45	.66	.90	1.19	1.52	1.89	2.32	2.79	3.32	3.91	4.56	5.29	6.09	6.96	29.5
30.0	.07	.17	.29	.46	.67	.92	1.21	1.55	1.93	2.36	2.84	3.38	3.98	4.64	5.38	6.19	7.08	30.0
30.5	.07	.17	.30	.47	.68	.93	1.23	1.57	1.96	2.39	2.89	3.43	4.04	4.72	5.47	6.29	7.20	30.5
31.0	.07	.17	.30	.48	.69	.95	1.25	1.60	1.99	2.43	2.93	3.49	4.11	4.80	5.56	6.39	7.32	31.0

Table 6

NET-LINE TABLE, GIVEN DIFFERENCE IN METRES, BETWEEN NET-LINE LENGTH AND VERTICAL DEPTH FOR VERTICAL ANGLES BETWEEN 4 AND 36 DEGREES

VERTICAL LENGTH (METRE)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	VERTICAL LENGTH (METRE)
3.0	.00	.00	.01	.02	.02	.03	.04	.05	.06	.07	.09	.11	.12	.14	.16	.19	.21	3.0
3.5	.00	.01	.01	.02	.03	.03	.04	.06	.07	.09	.10	.12	.14	.17	.19	.22	.24	3.5
4.0	.00	.01	.01	.02	.03	.04	.05	.07	.08	.10	.12	.14	.16	.19	.22	.25	.28	4.0
4.5	.00	.01	.01	.02	.03	.04	.06	.07	.09	.11	.13	.16	.18	.21	.24	.28	.31	4.5
5.0	.00	.01	.02	.03	.04	.05	.06	.08	.10	.12	.15	.18	.20	.24	.27	.31	.35	5.0
5.5	.00	.01	.02	.03	.04	.05	.07	.09	.11	.14	.16	.19	.22	.26	.30	.34	.38	5.5
6.0	.00	.01	.02	.03	.04	.06	.08	.10	.12	.15	.18	.21	.24	.28	.33	.37	.42	6.0
6.5	.00	.01	.02	.03	.05	.06	.08	.11	.13	.16	.19	.23	.27	.31	.35	.40	.45	6.5
7.0	.00	.01	.02	.04	.05	.07	.09	.11	.14	.17	.21	.25	.29	.33	.38	.43	.49	7.0
7.5	.00	.01	.02	.04	.05	.07	.10	.12	.15	.19	.22	.26	.31	.35	.41	.47	.52	7.5
8.0	.00	.01	.03	.04	.06	.08	.10	.13	.16	.20	.24	.28	.33	.38	.44	.50	.56	8.0
8.5	.01	.01	.03	.04	.06	.08	.11	.14	.17	.21	.25	.30	.35	.40	.46	.53	.59	8.5
9.0	.01	.01	.03	.05	.06	.09	.12	.15	.18	.22	.27	.32	.37	.42	.49	.56	.63	9.0
9.5	.01	.02	.03	.05	.07	.09	.12	.16	.19	.24	.28	.33	.39	.45	.52	.59	.66	9.5
10.0	.01	.02	.03	.05	.07	.10	.13	.16	.20	.25	.30	.35	.41	.47	.54	.62	.70	10.0
10.5	.01	.02	.03	.05	.08	.10	.13	.17	.21	.26	.31	.37	.43	.50	.57	.65	.73	10.5
11.0	.01	.02	.04	.06	.08	.11	.14	.19	.22	.27	.33	.39	.45	.52	.60	.68	.77	11.0
11.5	.01	.02	.04	.06	.08	.11	.15	.19	.23	.29	.34	.40	.47	.54	.63	.71	.80	11.5
12.0	.01	.02	.04	.06	.09	.12	.15	.20	.24	.30	.36	.42	.49	.57	.65	.74	.84	12.0
12.5	.01	.02	.04	.06	.09	.12	.16	.21	.26	.31	.37	.44	.51	.59	.68	.78	.87	12.5
13.0	.01	.02	.04	.07	.09	.13	.17	.21	.27	.32	.38	.46	.53	.61	.71	.81	.91	13.0
13.5	.01	.02	.04	.07	.10	.13	.17	.22	.28	.33	.40	.47	.55	.64	.73	.84	.94	13.5
14.0	.01	.02	.04	.07	.10	.14	.18	.23	.29	.35	.41	.49	.57	.66	.76	.87	.98	14.0
14.5	.01	.02	.05	.07	.10	.14	.19	.24	.30	.36	.43	.51	.59	.68	.79	.90	1.01	14.5
15.0	.01	.02	.05	.08	.11	.15	.19	.25	.31	.37	.44	.53	.61	.71	.82	.93	1.05	15.0
15.5	.01	.02	.05	.08	.11	.15	.20	.25	.32	.38	.46	.54	.63	.73	.84	.96	1.08	15.5
16.0	.01	.03	.05	.08	.12	.16	.20	.26	.33	.40	.47	.56	.65	.76	.87	.99	1.12	16.0
16.5	.01	.03	.05	.08	.12	.16	.21	.27	.34	.41	.49	.58	.67	.78	.90	1.02	1.15	16.5
17.0	.01	.03	.05	.09	.12	.17	.22	.28	.35	.42	.50	.60	.69	.80	.92	1.05	1.19	17.0
17.5	.01	.03	.06	.09	.13	.17	.22	.29	.36	.43	.52	.61	.71	.83	.95	1.09	1.22	17.5
18.0	.01	.03	.06	.09	.13	.18	.23	.30	.37	.45	.53	.63	.73	.85	.98	1.12	1.26	18.0
18.5	.01	.03	.06	.09	.13	.18	.24	.30	.38	.46	.55	.65	.75	.87	1.01	1.15	1.29	18.5
19.0	.01	.03	.06	.10	.14	.19	.24	.31	.39	.47	.56	.67	.78	.90	1.03	1.18	1.33	19.0
19.5	.01	.03	.06	.10	.14	.19	.25	.32	.40	.48	.58	.68	.80	.92	1.06	1.21	1.36	19.5
20.0	.01	.03	.06	.10	.14	.20	.26	.33	.41	.50	.59	.70	.82	.94	1.09	1.24	1.40	20.0
20.5	.01	.03	.07	.10	.15	.20	.26	.34	.42	.51	.61	.72	.84	.97	1.12	1.27	1.43	20.5
21.0	.01	.03	.07	.11	.15	.21	.27	.34	.43	.52	.62	.74	.86	.99	1.14	1.30	1.47	21.0
21.5	.01	.03	.07	.11	.15	.21	.28	.35	.44	.53	.64	.75	.88	1.01	1.17	1.33	1.50	21.5
22.0	.01	.04	.07	.11	.16	.22	.28	.36	.45	.55	.65	.77	.90	1.04	1.20	1.36	1.54	22.0
22.5	.01	.04	.07	.11	.16	.22	.29	.37	.46	.56	.67	.79	.92	1.06	1.22	1.40	1.57	22.5
23.0	.01	.04	.07	.12	.17	.23	.29	.38	.47	.57	.68	.81	.94	1.09	1.25	1.43	1.61	23.0
23.5	.01	.04	.08	.12	.17	.23	.30	.39	.48	.58	.70	.82	.96	1.11	1.28	1.46	1.64	23.5
24.0	.01	.04	.08	.12	.17	.24	.31	.39	.49	.60	.71	.84	.98	1.13	1.31	1.49	1.68	24.0
24.5	.01	.04	.08	.12	.18	.24	.31	.40	.50	.61	.73	.86	1.00	1.16	1.33	1.52	1.71	24.5
25.0	.02	.04	.08	.13	.18	.25	.32	.41	.51	.62	.74	.88	1.02	1.18	1.36	1.55	1.75	25.0
25.5	.02	.04	.08	.13	.18	.25	.33	.42	.52	.63	.75	.89	1.04	1.20	1.39	1.58	1.78	25.5
26.0	.02	.04	.08	.13	.19	.25	.33	.43	.53	.64	.77	.91	1.06	1.23	1.41	1.61	1.81	26.0
26.5	.02	.04	.08	.13	.19	.26	.34	.43	.54	.66	.78	.93	1.08	1.25	1.44	1.64	1.85	26.5
27.0	.02	.04	.09	.14	.19	.26	.35	.44	.55	.67	.80	.95	1.10	1.27	1.47	1.67	1.88	27.0
27.5	.02	.04	.09	.14	.20	.27	.35	.45	.56	.68	.81	.96	1.12	1.30	1.50	1.71	1.92	27.5
28.0	.02	.04	.09	.14	.20	.27	.36	.46	.57	.69	.83	.98	1.14	1.32	1.52	1.74	1.95	28.0
28.5	.02	.05	.09	.14	.21	.28	.36	.47	.58	.71	.84	1.00	1.16	1.35	1.55	1.77	1.99	28.5
29.0	.02	.05	.09	.15	.21	.28	.37	.48	.59	.72	.86	1.02	1.18	1.37	1.58	1.80	2.02	29.0
29.5	.02	.05	.09	.15	.21	.29	.38	.48	.60	.73	.87	1.03	1.20	1.39	1.60	1.83	2.06	29.5
30.0	.02	.05	.10	.15	.22	.29	.38	.49	.61	.74	.89	1.05	1.22	1.42	1.63	1.86	2.09	30.0
30.5	.02	.05	.10	.15	.22	.30	.39	.50	.62	.76	.90	1.07	1.24	1.44	1.66	1.89	2.13	30.5
31.0	.02	.05	.10	.16	.22	.30	.40	.51	.63	.77	.92	1.09	1.26	1.46	1.69	1.92	2.16	31.0

Measuring High Velocities

When measuring the discharge of flooding streams or during periods of rapidly rising or falling stage, it is often impossible to obtain accurate soundings and hence accurate measurements. Only excessive depths or velocities that are too great for the size of weight available make it necessary to use one of the following two methods during these conditions.

0.2 DEPTH METHOD

Provided that the stream bed is stable and a profile of the measuring section is available and approximate soundings can be determined, the 0.2 depth method can be used. Velocities at 0.2 depths are observed at selected verticals in the cross-section. The time required for the measurement should be such that any change in stage is minimal. If need be, a measurement can be obtained in a 15 to 20 minute time period by obtaining approximately 15 observations and reducing the time for each observation to between 20 and 30 seconds.

Make a complete measurement as soon as possible after obtaining a 0.2 measurement. Use the results to correct the approximated depths if standard soundings were not available for the partial measurement. Next determine the relationship between the 0.2 depth velocity and the mean velocity at each location where observations were made during the earlier measurement. Use this relationship to convert the 0.2 depth velocity observations of the partial measurement to mean velocity and compute the measurement in the normal manner.

Where it is not possible to obtain a follow-up measurement for the technique just described, the discharge for the 0.2 depth method can be computed in another manner. Previous measurements are recomputed using the 0.2 depth velocity in place of the mean velocity. A relationship is then plotted using as coordinates the recomputed 0.2 depth discharges and the actual discharges. From the plot of these results a curve of relationship can be drawn which is often a straight line. The actual discharge for the partial measurement can be determined from this plot.

This method should be used with caution where there is a flow distribution change caused by backwater or rapid change in discharge.

SURFACE VELOCITY METHOD

The flow of debris during floods will often prevent observations from being made at the 0.2 and 0.8 depths at all sections in the stream cross-section. Surface velocities should be obtained at as many of these otherwise unmeasurable sections as possible. This method requires that the meter be placed at least 0.5 m beneath the water surface to avoid the possibility of the velocities being affected by surface disturbances.

A complete discharge measurement must be obtained as soon as the flow of debris has subsided. Surface velocities as well as those at the 0.2 and 0.8 depth positions must be obtained for each section where, during the previous measurement, only surface velocities were observed. The depth values obtained are used as standard soundings and the computed coefficients are applied to that portion of the earlier measurement where only surface velocities were measured. If there is little variation, only one coefficient need be used for the entire cross-section; otherwise, a coefficient must be applied separately to the values in each section.

Again it must be stressed that these techniques have limitations. They cannot be applied where stream bed instability is such that reliable soundings cannot be obtained.

DISCHARGE MEASUREMENT COMPUTATION

NOTE:

Over the years the term "section" has been used in an imprecise manner. In some instances it is used to denote the metering section or entire cross-section, in others it is used when referring to any one part of the cross-section. In the following discussion of discharge measurement computations, the term section shall refer to that small portion of the cross-section that is bounded by imaginary verticals at one-half the distance to the preceding and one-half the distance to the following verticals at which an observation of sounding and velocity are made (Figures 18 and 19).

Mean Section Method

Prior to October 1950 the computation of discharge measurement notes was by the mean section method. With this method the product of the mean of the depths and the mean of the velocities observed at adjacent verticals is multiplied by the width between the verticals to determine the discharge for each section. The discharge for a section is represented by:

$$q = \frac{\bar{v}_1 + \bar{v}_2}{2} \cdot \frac{d_1 + d_2}{2} \cdot b \qquad (2\text{-}1)$$

where:

q = discharge for one section
v = velocity in the vertical
d = depth at the vertical
b = width between two verticals

This is repeated for each consecutive section across the stream and the total discharge for the stream is then obtained by adding together all of the partial discharges. A study in 1950 showed that the results of discharge measurements obtained by this method are slightly less accurate and more difficult to compute than those obtained by the mid-section method. Consequently, the mid-section method has been used by the Water Survey since that time.

Mid-Section Method

The mid-section method of computing discharge measurements differs from the previous method in the following ways:

1. The observed depth at the vertical is considered to be the mean depth for the section.

2. The assumption is made that the mean velocity at the observation vertical represents the mean velocity for the section.

3. The width for each section is computed as one-half the distance from the preceding vertical plus one-half the distance to the following vertical.

Thus in the illustration Figure 17, the discharge for the heavily outlined section at distance b_6 from the initial point is computed as:

$$q = v_6 d_6 \frac{b_7 - b_5}{2}$$

The calculations for the first and last sections of a discharge measurement are handled in much the same manner as just described. The main difference is in the determination of the widths. Since at the beginning and the end of a measuring section there is no preceding or following vertical, the width becomes one-half the distance from the edge to the first vertical or from the last vertical to the edge. Figure 18 shows typical edge sections. As a result of the computational procedures, in these instances an area and discharge are not derived for the edge sections. Therefore when making a discharge measurement the first and last verticals should be taken as close to the edge as possible. The two edge sections will then be very small in proportion to the total measurement and an estimated discharge for these sections will introduce very little if any appreciable error.

An edge section will also occur where there is a vertical drop at the water's edge such as at a pier, a bridge abutment or a wingwall. Again, the width calculation is one-half the distance from the previous or to the following vertical as shown in Figure 19. Here however, an area and discharge can be computed. Once again, try to arrange soundings so that edge sections are made as small as possible. Keep in mind that caution is to be exercised when observing depths and velocities close to piers and abutments. At times, it may be necessary to estimate these values to avoid the possibility of the meter and weight assembly being damaged against the pier or abutment. In some instances, debris will have lodged on or against the pier and this further complicates matters. Where these situations are encountered, it becomes necessary to estimate the discharge for the panel adjacent to the pier by estimating the depth from the previous vertical and the velocity which is expressed as a percentage of that observed at the previous vertical.

The technique described in the previous paragraph can also be applied where an abrupt and large change in depth is encountered in a measuring section

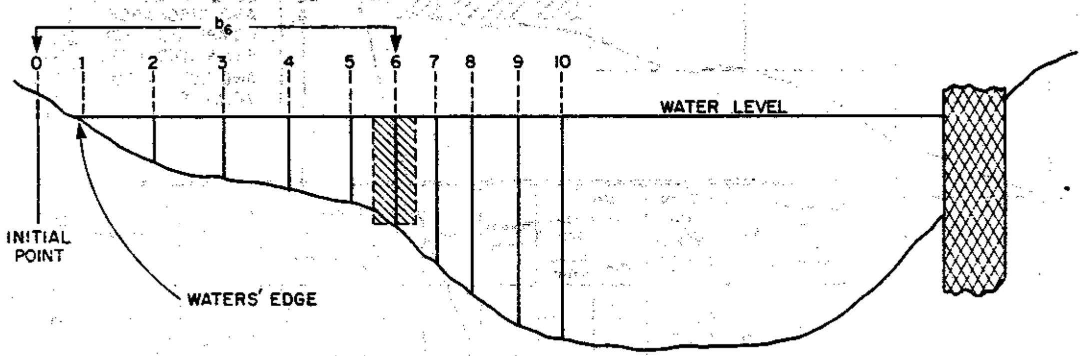


Figure 17

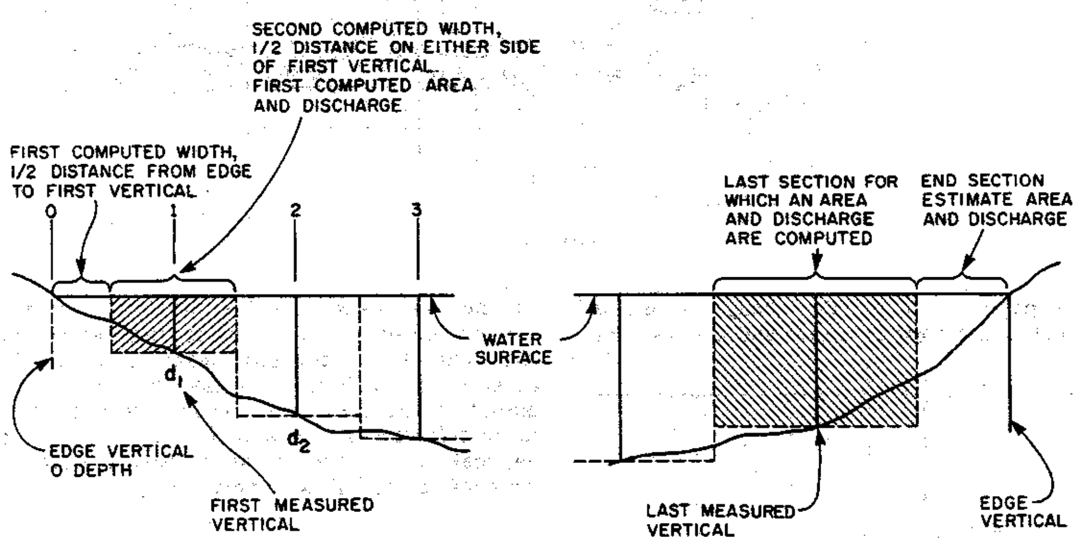
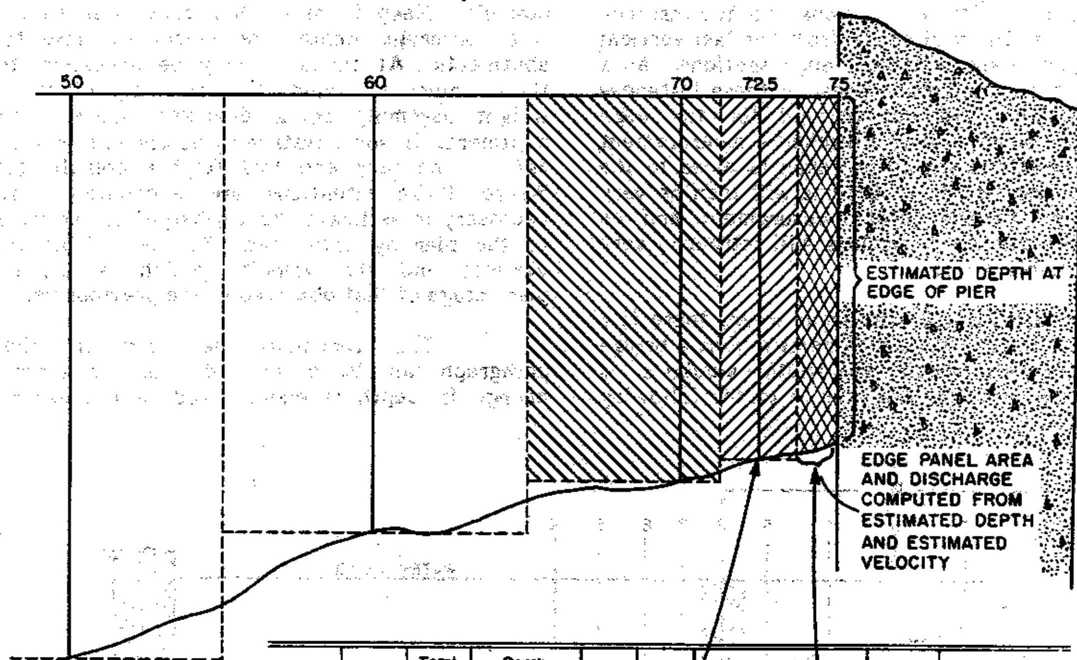


Figure 18



Distance from inital point	Width	Total depth W.S. to bottom ice	Depth under ice: Of water	Depth under ice: Of observation	Revolutions	Time	Velocity: At point	Velocity: Mean	Area	Discharge	.85
50	10	17.25							172.5		.90 .92
60	10	14.90							149.0		.94
70	6.25	12.52							78.25		.96 .97
72.5	2.5	12.05			30	43⁻	4.77	0.457	30.13	13.8	.98
					30	47⁻	4.37				.99
75.0	1.25	11.00e	edge	of pier	vel 2/3 of		72.5	0.305	13.75	4.19	
pier											1.00

Figure 19

(Figure 20). The point at which the change occurs is treated as though it is the edge of a pier and the distance to the observation vertical is listed twice. Depth and velocity observations are made just before and just after the point where the change takes place. By doing this the observations of depth and velocity from either side of the abrupt change are treated separately, one set being applied to an effective width of half the distance to the previous vertical, the other to an effective width of half the distance to the following vertical.

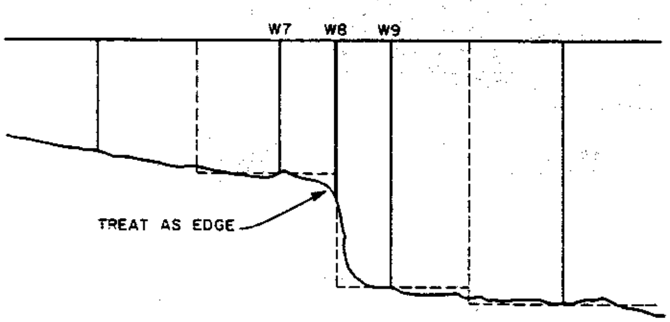


Figure 20

A DISCUSSION OF ERRORS AFFECTING THE ACCURACY OF STREAMFLOW MEASUREMENTS

ntroduction

Much has been written in an attempt to quantify he various partial and combined errors that make up the robable accuracy of a streamflow measurement. Results rom various analyses generally show that accuracies of ithin 5% are achievable 95% of the time, provided that he field data have been obtained in accordance with an cceptable standard.

Streamflow measurements by the conventional urrent meter method require the measurement of widths, epths and velocities. Inaccuracies can occur during the ıeasurement of any of these parameters through errors ıtroduced by technique or equipment used. These can be ategorized as human, systematic or random errors. The urpose of this discussion is to identify some of the more ommon factors which lead to inaccuracies when observing hese parameters.

Vidth Measurement

Under most discharge measurement conditions, ıeasurements of the overall width and of distances etween verticals can be made with precision and normally o not contribute to overall error in a discharge ıeasurement. Human errors can and do arise when units f unconventional spacing are used on cableways, bridges nd other measurement structures. Another source of rror is encountered when spacings on structures have been hanged and the old markings have not been completely radicated. Confusion can be avoided by clearly marking ıe spacing of the intervals on the cableway, A-frames and ıeasurement structures. It is absolutely essential that all f this information be recorded on the station description.

Relatively small systematic errors can be ıtroduced if cableways with long spans (250-300 m or ıore) are marked with distances along the cable rather ıan with horizontal distances. The errors in spacing of erticals will gradually become larger at either end of the able where the slope is greatest, and least in the centre ection. The overall effect on the discharge measurement ill depend on the flow distribution across the stream.

Errors can also be introduced when positioning oats by using survey instruments such as sextants, ıeodolites and electronic distance measuring devices. uman errors may be made when reading the instruments ıd systematic errors may result from instrument alibration. Most significant errors, however, will be ındom in nature and will result from the manner in which ıe boat is actually positioned. If the boat is ee-positioned, that is, held in position by motor thrust one, positioning error will depend entirely on the ability the boat operator. If the boat is anchored, positioning ror will depend upon the type of anchorage used.

epth Measurement

Depth observation may be made using sounding ods, sounding cables and echo sounders. Both systematic ıd human errors can occur when using any of these. Samples are incorrect reading of a graduated rod or failure to take into account the distance between the current meter and the sounding weight. Systematic errors will also result from using an echo sounder with the instrument not properly calibrated. Random errors, however, are the major errors that can be expected.

It is often difficult to accurately define the cross-sectional area of shallow streams strewn with boulders. Inaccuracies arising from this can be reduced by increasing the number of soundings. The base of a sounding rod may be allowed to sink into the soft stream bed when sounding silty streams, thus causing oversounding. When metering from ice cover, defining the bottom of the ice surface usually presents no problem but defining the slush horizon can at times be extremely difficult.

Although problems of oversounding and undersounding can arise when using cable suspended systems, the most significant errors are most often introduced with the application of wet and dry line corrections. These are based on assumptions concerning the drag forces on the sounding line, the meter and the weight assembly. Wet and dry line corrections become more significant as the distance to the water surface and the drag forces on the sounding line and meter and weight assembly become greater. However, as a general rule, the overall effect of sounding errors on a discharge measurement are greatest for streams with shallow depths and least on deep streams.

Other Errors

Other sources of significant error in a discharge measurement are those that relate to the measurement of velocity. Among the more readily apparent are those associated with the calibration of current meters, the direction of flow, the duration of observation time, and the number of observation verticals as well as the number of observation points in each vertical.

CALIBRATION OF CURRENT METERS

The Water Survey of Canada has maintained as a standard, that all current meters have individual calibrations. These are obtained by towing the meters through a tank of still water at velocities from 4.5 to 300 cm/s and from this, individual calibration curves are developed. Although it is generally accepted that this procedure is equivalent to the stream gauging situation where the meter is held in flowing water, there is some question about the validity of this assumption when using the meter (particularly cup type meters) under turbulent flow conditions. Analysis of a number of current meter calibrations show that there is a standard error of less than 0.007 m/s. There are, however, other factors that may cause errors larger than this.

It should be noted that the standard Price current meters used by the Water Survey of Canada have a tendency to become less accurate when used for measuring low velocities, those in the order of 0.05 m/s or less. This is often due in part to poorly prepared or damaged bearing surfaces and pivots, or to binding in the penta gear systems. In other cases, current meters are poorly maintained or have not been included in a regular recall and inspection program. Current meters can be and often are specially prepared and rated for measuring very low velocities, but this is done only on request. See Instruments, Equipment and Equipment Assemblies, Price No. 622 Type AA meter.

The current meter is subject to both surface and bottom effects in shallow streams. These effects generally become significant when depths are less than 0.2 m. In very shallow depths, where the cups are partially submerged, the meter tends to over-register. Under-registration occurs when the meter cups are placed too close to the stream bed. The magnitude of these effects depends upon the channel roughness and the velocity of the water.

Methods of suspension other than the standard recommended methods will also have a decided effect upon the accuracy of the current meter. Meters are calibrated using cable suspension and a 30 lb weight. The results when using other recommended suspension methods are within 1% of the calibration values and will therefore produce an error of little or no significance.

DIRECTION OF FLOW

Discharge measurement cross-sections are usually chosen so that the flow is perpendicular to the cross-section. Even though they are carefully selected, it is not always possible to avoid oblique flows at some of the verticals. At these verticals the velccities must be corrected by applying an appropriate cosine coefficient. Random errors may be introduced when observing the angle of flow, or when it is assumed that the angle observed at or close to the water surface remains the same throughout the entire depth.

Other sources of error can be introduced when using rod suspensions and in particular when winter rod sets are used in deep, fast flowing water. Although the current meter can be misaligned both vertically and horizontally with the direction of flows, the most significant error will result from vertical misalignment. The current meter will underregister if tilted above or below the horizontal, and the magnitude of the error will depend upon both the velocity of the water and the angle of departure.

DURATION OF OBSERVATION TIME

Pulsations, random in nature, are evident in all streams even though flow conditions are essentially steady. Since pulsations are random in nature, the effects of pulsation will be eliminated when velocities are observed for a sufficient length of time. In actual practice during a discharge measurement, velocities are observed for relatively short periods of time. The expectation is that a sufficient number of observations will be made so that pulsation effects will tend to cancel each other during the course of a measurement. Studies have shown that at low velocities, pulsation effects are usually greatest. Studies have also shown that the optimum observation duration is between 40 and 60 seconds and that ac acy decreases significantly if a duration of less than 30 seconds is used; for durations longer than 60 seconds, the increase in accuracy generally is negligible.

NUMBER OF OBSERVATIONS

Number of Observation Verticals

There are two ways in which the accuracy of a discharge measurement can be significantly affected by the number and distribution of observation verticals. First, the observation verticals are used to define the channel cross-sectional area. Appreciable errors will be introduced if the number of observations made to define the cross-section are not sufficient to do the job. This particular problem can be overcome by obtaining additional depth observations.

Secondly, the velocity observations in the verticals are used to define the mean velocity in the cross-section; therefore, the verticals should be spaced so that the velocities observed are more representative of those in the preceding half panel and the following half panel.

The spacing of observation verticals can be accomplished on the basis of either the equal flow method, the equal width method or a combination of both. With the equal flow method, the width segment can change frequently and, using the mid-section method for computations, the horizontal velocity profile tends to be distorted. That is, if the width segments change frequently, the observed velocities will not occur at the midpoint of the panels.

A good compromise is to use the equal width method and to change the spacing of verticals only a few times during a measurement to accommodate any significant changes in flow distribution.

Studies on measurement accuracy have shown that accuracy tends to be low when fewer than 15 verticals are used but the improvement becomes negligible when more than 35 verticals are used. All else being equal, the use of 20 to 25 verticals would seem to be ideal.

Number of Observation Points in a Vertical

The mean velocity in a vertical is normally obtained by measuring at one or two points in that vertical. Comparison of these observations with those obtained by some detailed method (a mean of observations at every tenth of the depth plus half the value observed at the surface and half the value at the bottom), indicate that random errors do occur when determining the mean velocity in any given vertical. Furthermore, the one point method is usually not as accurate as the two point method. Nevertheless, surface and bottom effects become significant as the stream depths decrease and when depths are less than 0.75 m the one point method should be used.

CONCLUSIONS

Errors in the measurement of width, depth and velocity as well as the lack of care in choosing the number of verticals and observations in a vertical, all combine to reduce the overall accuracy of a discharge measurement. To a large extent, human errors can be avoided by careful attention to detail and by adhering to established and proven techniques and routines. Systematic errors can be reduced significantly by proper maintenance and calibration of instruments and equipment and by adequate training of field officers. However, random errors will always occur. A significant reduction in these errors can be achieved if the field officer obtaining the measurement can recognize the potential problem areas and takes the appropriate precautionary measures to avoid or minimize them. One possible indication of measurement accuracy can be obtained by conducting several consecutive or simultaneous measurements and by using different sets of equipment and techniques.

INSTRUMENTS, EQUIPMENT AND EQUIPMENT ASSEMBLIES

1. Current Meters
   - Horizontal Axis Meters
   - Vertical Axis Meters
     - Price No. 622 Type AA
     - W.S.C. Winter Meter
     - Pygmy Current Meter
   - Care and Maintenance of Current Meters
2. Wading Road
3. Winter Rod Set
4. Sounding Reels
   - Type A-55 Reel
   - Type B-50 and B-56 Reels
   - Type E-53 Reel
5. Handline
6. Weight Hangers, Connectors and Sounding Cable
   - W-2 Hanger Bar
   - BC-1 Hanger Bar
   - Connectors
   - Sounding Cable
7. Metering Frames
8. Type A Crane

Description

1. Current Meters

The most commonly used current meters are of two general types, the cup type with a vertical axis of rotation and the screw or propeller type which rotates about a horizontal axis. With either, the velocity of the water at the point where the current meter is placed is determined from the rate of rotation of the bucket wheel or propeller. The relationship between the rate of rotation and the velocity of the water is established in a towing tank for every current meter prior to placing it in service.

A. Horizontal Axis Meters

Aside from special applications such as in the Moving Boat and VADA (velocity-azimuth-depth-assembly) discharge measurement techniques, the propeller type current meter is used to a very limited extent by the Survey. Among others, some of the disadvantages encountered with this type of meter are: 1) the effects of slight damage to the rotor can seriously alter the rating and the damage cannot readily be repaired in the field; 2) the horizontal bearings are extremely difficult to keep free from silt which will cause changes in friction and a resulting change in the rating of the meter; 3) more than one rotor is necessary to sample the range of velocities encountered during one discharge measurement. A light rotor, with vanes that are at an abrupt angle to the current, is required to sense accurately low velocities, while one with vanes at a lesser angle is necessary to overcome the problem of the rotor revolving too fast in high velocities.

Among the advantages found with this type of meter are: the lack of sensitivity to turbulence or vertical movement that could be encountered during measurements from a boat, or a cableway that is subject to vertical motion; component propellers are available that will automatically register the component velocity along the axis of the meter for currents that are oblique to it.

B. Vertical Axis Meters

a) Price No. 622 Type AA

The Price current meter is used almost exclusively by the Water Survey in its streamflow measurement program. The name is derived from W.G. Price, who was responsible for the original design of this meter. The Gurley Co. the first to manufacture it, assigned it their catalogue number, No. 622. The type AA identifies the meter as having a deeply seated lower bearing and pivot assembly.

The key feature of this Price meter is that both the upper and lower bearing surfaces are located in fairly deep inverted cavities which trap air when the meter is placed in water. This effectively excludes water and silt from the bearing surfaces, eliminating undue wear and a resulting change in the meter rating.

Extensive research and experimentation has shown this meter to be rugged, reliable and well suited to the wide variety of conditions it is subjected to in the field. In addition, only one bucket wheel assembly is required for the entire range of velocities encountered during normal stream gauging operations. The meter will respond accurately to velocities that range from 4.5 - 300 cm per second, providing that it is properly maintained.

The main components of the meter are the pivot and bucket wheel assembly, the contact chamber and the yoke and tail assembly. The bucket wheel has six conical shaped cups and is 125 mm in diameter. The letter "T" stamped on the inner portion of the frame indicates the top side of the bucket wheel. When in use, the bucket wheel rotates in a counter-clockwise direction.

The contact chamber is fitted with a bearing, a penta gear for indicating each five revolutions of the bucket wheel and two insulated binding posts each having a fine contact wire. Two types of contact wire are commonly used. One is a bronze multi-strand wire with a bead of solder at the contact end, the other is a single strand of stainless steel wire. One wire makes contact during each and every revolution of the bucket wheel, the other makes contact with the penta gear and indicates every five revolutions of the bucket wheel.

The top of the rotor shaft is rounded to provide a smooth surface where it comes in contact with the bottom of the chamber cap. Immediately below the rounded end, an eccentric is cut in the shaft. This is the means by which the shaft makes contact with upper contact wire once during each revolution of rotor. The next section of the shaft fits into the contact chamber bearing lug. A short section of acme thread is cut into the shaft below the bearing section. This meshes smoothly with the penta gear fitted in the bottom of the contact chamber. The penta gear has two tabs, each of which brushes the lower contact wire once during every five revolutions of the rotor.

There are at times requirements for specifically prepared meters for measuring very low velocities. The Price meter can be modified by removing the penta gear from the bottom of the contact chamber. This permits a slight reduction of friction in the rotor movement and the meter should be specifically rated for this condition.

An accessory for the Price current meter is the magnetic switch contact chamber. A 13 mm long permanent magnet is embedded in the top portion of the rotor shaft which fits into the centre of a special contact chamber. A magnetic reed switch which is accessible from the top of the assembly, is located in a chamber adjacent to the rotor chamber. The binding post and insulating bushing seal this chamber. During each revolution of the rotor shaft the magnet passes this chamber which contains a reed switch. There is a momentary but positive closure of the switch. This system is used because the magnetic reed switch will produce a "clean" signal for triggering an automatic electric pulse counter. The wiping action in the contact wire style chamber produces an erratic signal when the rotor revolves slowly. This produces more than one signal and therefore cannot be used with an electric counter. If the reed relay system is used with a headset, care should be taken to use the proper power supply to prevent arcing of the contacts.

b) W.S.C. Winter Meter

Except for the yoke design, this current meter is identical in every respect to the Price No. 622 Meter. It was developed to permit easy passage of the meter through holes drilled in the ice for winter discharge measurements. Since the distance from the front of the bucket wheel to the back of the yoke is 152 mm, a hole through the ice cover with a minimum diameter of 200 mm is required to permit easy passage of the meter. This is obtained by using the standard ice auger cutter head.

The meter is used primarily with the winter rod set. The threaded boss on the upper limb of the yoke permits it to be attached to the bottom rod of the set. This is also the means by which it is mounted in any of the winter weight assemblies. A small brass adapter threaded into the boss is required for mounting the meter in any one of the three winter weight assembly frames. The assembly can then be suspended by hand line or from a sounding reel mounted on a winter metering sled or frame.

The magnetic reed switch contact chamber and electric pulse counter are accessories that are often used with the W.S.C. Winter Meter.

c) Pygmy Current Meter

A situation is often encountered where depths are insufficient for obtaining accurate velocity observations with the larger Price meter. The Pygmy meter is approximately two-fifths the size of the Price No. 622 meter and was designed for measuring shallow streams.

As for all other current meters, individual calibrations are maintained for the Pygmy meters. The major difference is that the Pygmy meters are towed at lower velocities, from 2.5 to 140 cm/s.

Aside from size, there are other significant differences between the two meters. The Pygmy meter contact chamber and yoke are one unit and the chamber has only one contact wire that signals each revolution of the bucket wheel shaft. The meter is meant to be mounted on a wading rod and since it is used in very shallow depths, it is not provided with a tailpiece nor is there provision for suspending it from a cable.

The bucket wheel is only 50.8 mm in diameter and it revolves at a rate that is 2 1/4 times as fast as the larger Price meter. As a result of the bucket wheel revolving so rapidly, the use of the meter is limited to measuring velocities that are not in excess of 1 m/s unless an automatic pulse counting device is used. When not in use, this meter must always be fitted with the brass pivot provided. The bucket wheel is not equipped with a raising nut and the pivot and bearing can be damaged if the steel pivot is not removed.

C Care and Maintenance of Current Meters Price No. 622 Type AA

Regular cleaning and oiling of a current meter is of the utmost importance. At the same time it should be carefully examined to make certain that all parts are in good working order. Normally, cleaning and lubrication is carried out at the end of each day. If, however, the meter has been used in a stream that is heavily laden with suspended sediment, it should be cleaned immediately after the measurement. This will help prevent abrasive particles from causing premature and unnecessary wear to the bearing surfaces. The reliability of the Price meter depends, like any other good quality precision instrument, upon the care and maintenance the instrument receives.

When cleaning a meter, the contact chamber and pivot must be removed from the yoke. This will permit the bucket wheel assembly to be tipped clear of the lower limb and the tungsten carbide pivot bearing can then be cleaned and examined with relative ease. At the same time the pivot can be cleaned and oiled. Particular care should be taken to inspect the point on the pivot for signs of wear or roughness. The bucket wheel shaft should be thoroughly cleaned making certain that fine particles of grit haven't lodged in the acme threads. In the contact chamber, the penta gear teeth and the shaft bearing should be carefully cleaned. All parts must then be well lubricated with a good quality instrument oil.

During reassembly of the meter, take particular care to properly align all parts. The contact chamber must be fully seated in the upper limb of the yoke. Before tightening the set screw, position the shaft bearing in the chamber directly over the axis of yoke. Tighten the set screw and replace and tighten the contact chamber cap. Next, invert the meter and insert the pivot through the hole in the lower limb of the yoke. The tapered flat on the pivot must face the set screw in the yoke. The set screw is then tightened.

There should be 0.008 inch (0.20 mm) end play between the pivot and the pivot bearing when the meter is completely assembled and in correct adjustment. To adjust the pivot correctly, the following steps must be followed. Loosen the set screw in the pivot nut and then the set screw in the lower limb of the yoke. With the meter inverted, back off the pivot adjusting nut and insert the pivot so that there is no end play in the assembly. Now tighten the pivot nut until it rests against the lower limb of the yoke. Turn the pivot nut an additional one quarter turn and lock it in position with the small set screw. Tighten the set screw in the yoke and the adjustment is completed.

The most common causes of damage to a current meter result from improper handling and from debris striking the meter during measurements. Prevent accidental damage to either the point of the pivot or the pivot bearing when the meter is not in use. The bucket wheel assembly must be kept raised on the raising nut. To use the raising nut correctly, hold the bucket wheel stationary and turn the raising nut until snug. Any undue force such as that capable of being exerted by holding the raising nut and turning the bucket wheel, can cause the shaft to be bent or if enough pressure is exerted, the yoke can be sprung. The upper section of the shaft can also be

1 BUCKET-WHEEL HUB
2 BUCKET-WHEEL HUB NUT
3 BUCKET-WHEEL
4 BUCKET-WHEEL SHAFT
5 RAISING NUT
6 PIVOT
7 SET SCREW
8 PIVOT ADJUSTING NUT
9 ADJUSTING NUT SET SCREW
10 ACME THREAD
11 CONTACT CHAMBER
12 CONTACT CHAMBER CAP
13 BINDING POSTS
14 HANGER SCREW
15 TAIL FIN SET SCREW
16 CURRENT METER YOKE

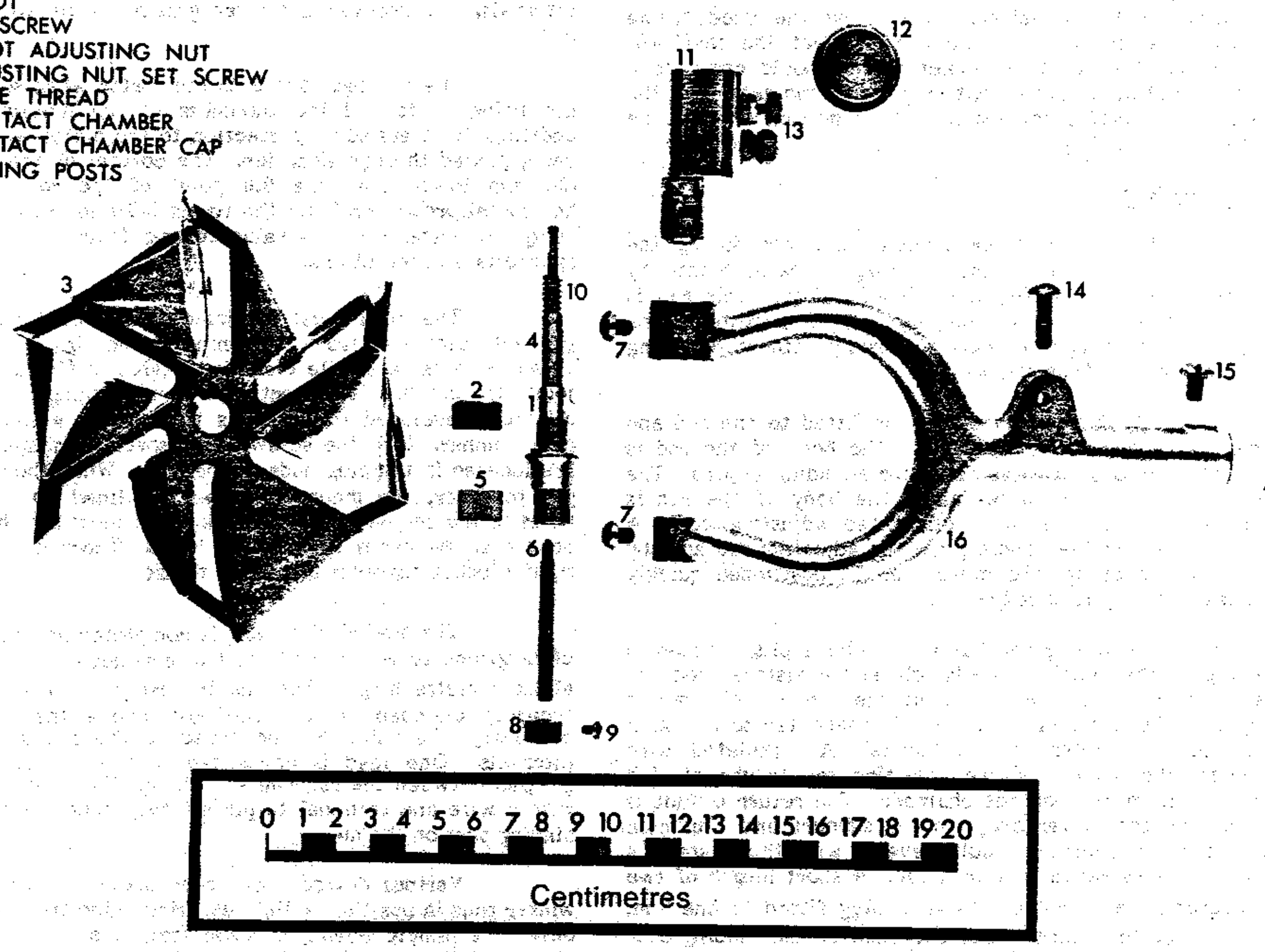
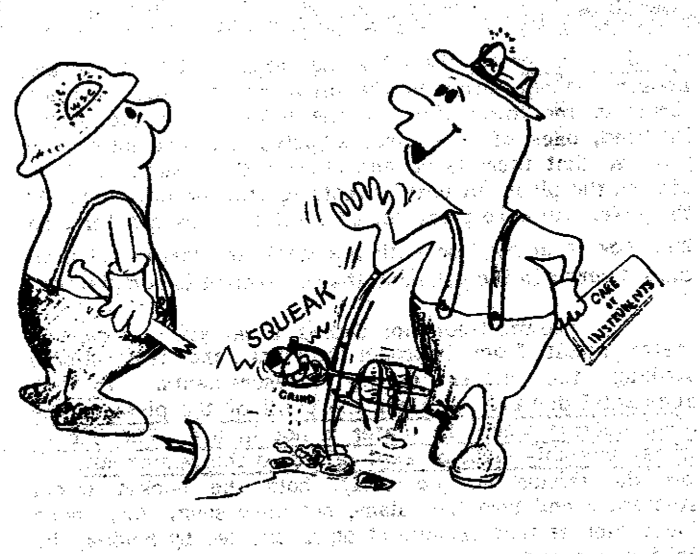


Figure 21



bent if an attempt is made to remove or replace the contact chamber cap when the bucket wheel hub assembly is in the raised position.

The shaft, the bucket wheel frame, or both, can also be bent by an accidental blow received during the course of a discharge measurement. To check the meter for a bent shaft, damaged pivot or bent bucket wheel, rotate the bucket wheel slowly. Observe the wheel frame for trueness and at the same time inspect the shaft for alignment. The rotating bucket wheel should come to a very gradual stop. An abrupt stop would indicate that the bearings or pivot point are in poor condition or that the penta gear is binding.

2. Wading Rod

The rod used for sounding and positioning the current meter while making discharge measurements by wading is called the Dry-Hand Wading Rod. This rod is about 1.3 m long and is so designed that the position of the meter can be changed quickly and easily without removing the meter or rod from the water.

A 76 mm diameter base is fitted to one end and a calibrated handle to the other. The body of the rod is graduated in 20 mm increments for sounding depths. The meter support which slides along the body of the rod is fastened to the end of a calibrated adjusting rod. A friction brake in the handle grips the adjusting rod and, by releasing the brake, the meter can be positioned quickly and easily at any required depth.

The wading rod has a headphone plug located in the top of the handle. The handle and adjustable rod are insulated from the main body of the rod and the meter support. One terminal of the plug is connected to the main body and the other to the handle. An insulated wire connects the bottom of the adjusting rod to the binding post on the meter contact chamber. The return circuit is by way of the meter body, meter support and the main rod. If a short circuit should develop with this system, a quick and easy repair can be made. A short length of two conductor wire is required with a plug fitted to one end. One lead of the other end is attached to the binding post and the other to the body of the meter.

In either case, make certain that the electrical wire leading to the contact chamber is secured in a manner that prevents it from interfering with the bucket wheel during a measurement.

When determining depths, place the rod vertically in the water with the base resting on the bed of the stream. The depth is observed on the graduated main body of the rod. To set the meter at the 0.6 observation position, release the brake and move the adjustable rod and handle. The depth in metres is represented by the numbers stamped in the adjustable rod and the tenths by the numbers stamped in the handle.

It is often desirable to use the 0.2 and 0.8 method of observing velocities while making a wading measurement. The corresponding meter positions can be set on the rod as described in Discharge Measurements, Measurements by Wading.

3. Winter Rod Set

The winter rod set normally includes four sections of rod and a rod base. The rods are 20 mm in diameter and all but the bottom section to which the meter is attached, are 1 m long. The depth of water is read from graduations marked on the body of the rod. Grooves are cut at each 20 mm interval, but at 0.1 m and 0.5 m intervals, two grooves and three grooves respectively, are cut.

The rod base protects the meter when soundings are being made and the thickness of ice measured. In addition, it offers some protection to the meter while it is being passed through slush ice. The bottom of the base is 100 mm lower than the 0.0 point of the rod and the horizontal protrusion from the top is 100 mm above. When using this base, add this value to and deduct it from the appropriate observations.

The rods must be joined together securely to prevent sections from loosening when in use. With threaded rods, a simple clamping device is fitted at each joint to prevent the sections from turning. A more recently developed rod set fits together in a socket and plug manner. Machine screws with specially shaped heads are located in the plug ends of the rods. When the rods are put together, the machine screws are lined up with the holes in the socket ends and backed out until the shoulders on the screw heads lock in the holes. The rods are now rigidly locked together and ready to use.

The electrical circuit is completed using a length of neoprene or rubber-coated, two-conductor cable that is about a metre longer than the full rod set. The cable is securely clamped to the rod just above the base. If necessary, the cable can be taped to the rod at regular intervals. One lead is connected to the rod or can be gripped between the rod and the clamp, the other is fitted with a wire and terminal to permit easy connection to the binding post on the meter.

Various devices have been made for holding the winter rods in position while measuring velocities under ice cover. A simple holder is made from a short section of discarded hockey stick. This is illustrated in Figure 22.

Another method uses the two conductor cable itself, as long as the cable is well secured to the bottom section of the rod.

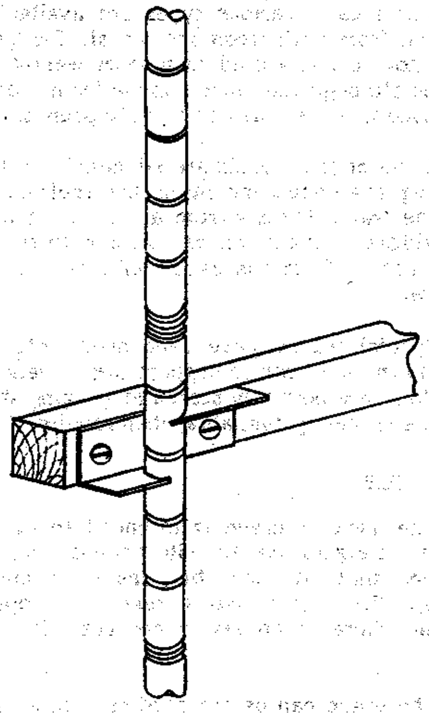


Figure 22

4. Sounding Reels

Sounding reels are used to raise, lower and position the current meter and weight assembly when making discharge measurements. Reels are equipped with a depth indicator, electrical connector and a level wind device to lay the cable in a smooth and single layer on the drum. Three different sizes of reel are used for the different field conditions encountered. They are the types A, B and E (Type D reels are seldomly used now). All reels have the same base bolt pattern and as such can be used interchangeably with cranes, mounting brackets on cable cars, boat frames and winter metering sleds.

Type A-55 Reel

The light-weight, compact, type MA-55 reel is a general purpose reel that can be mounted on a bridge frame, type A crane, boat frame or on a reel bracket fixed to a cable car. The reel is normally used with weights of 75 pounds or less, but can, if necessary be used with 100-pound weights.

The reel is equipped with a ratchet and pawl which must be disengaged to lower the meter and weight assembly. The raising and lowering of equipment is controlled with the crank. Up to 25 m of 1/10-inch cable can be wound in one layer on the drum, the circumference of which is such that, for each revolution, the meter assembly can be raised or lowered 0.3 m.

Type B-50 and B-56 Reels

The type B sounding reels are required for weights weighing 100 pounds and more. The drums will hold approximately 45 m of 1/10-inch or 36 m of 1/8-inch cable. The brake/clutch system is a desirable feature for sounding great depths. This also makes it ideally suited to metering from high structures even when using the lighter 50 and 75-pound weights.

For bridge measurements, the reels can be mounted on a type A crane, a specially manufactured frame for use on small cable cars or on boat frames or on deck-mounted cranes for boat measurements.

The B-56 is the more versatile of the two reels since it can be either hand operated or motor driven through a double "V" pulley to a jack shaft. The jack shaft and reel gears remain engaged at all times thus enabling equipment to be both raised and lowered by motor.

Type E-53 Reel

The E reel is intended primarily for power operation and is required for the heaviest weights and samplers used for discharge measurements. The reel is driven through a jack shaft which has a crank actuated friction brake permanently attached to one end.

The positioning of metering or sampling equipment is accomplished entirely using the power unit and by manupulating the brake crank. A hand crank can be fitted to the pulley end of the jack shaft for retrieving equipment in the event of failure of the power unit.

5. Handline

A handline is a compact item of equipment that can be used with weights of 50 pounds or less and provides a simple means of suspending a current meter and weight assembly. It can be easily stored or carried to a metering site and is particularly useful where it is necessary to walk long distances to reach a measurement section. It is often used for this reason at winter metering sites.

In the event of failure of regular suspension equipment, the handline can be used as a substitute. The only limiting factors are excessive depths, high velocities and heavy weights.

6. Weight Hangers and Connectors

Weight hangers fabricated from stainless steel are used to attach both the current meter and sounding weight to the connector at the end of a sounding cable or handline. The two types commonly used are the m-2 and BC-1.

M-2 Hanger Bar

This hanger is 12 5/8" x 5/8" x 1/8" and is used for weights up to and including 100 pounds. A 5/16" hole is provided at one end of the bar for attaching it to the connector; the other end has a hole drilled and threaded to accept either the short or the long 3/8" hanger pin.

Two 1/4" holes are drilled along the body of the rod for attaching the current meter. These are located at

180 mm and 260 mm above the weight hanger pin so as to position the meter at 0.21 m and 0.22 m above the bottom of the 15- and 30-pound weights. The meter is positioned in the upper hole when used with the 50, 75- and 100-pound weights. This places the meter 0.31, 0.32 and 0.33 m above the respective weights.

The numbers 15 and 30 are stamped above the lower hole to indicate the correct position for the meter when either the 15- or 30-pound weight is used. When used with the 50- 75- or 100-pound weight, the meter is positioned in the upper hole. M-2, the model number of the hanger is stamped on the body of the hanger.

BC1 Hanger Bar

This hanger bar is larger than the M-2 model and is used for weights of 100 pounds and greater. The hanger is 21 5/8" x 3/4" x 1/8" with a 3/8" hole at one end for attaching to the connector and a 3/8" threaded hole at the other end for the weight hanger pin.

Two 7/32" holes for positioning the meter are located at 10.3" and 19.5" above the weight hanger pin. Mounted in the lower position, the meter is approximately 1 foot above the bottom of the 100-pound weight. In the upper position, the distance above the bottom of the weight is approximately 1.8 feet. A special rating for the current meter must be obtained when using this hanger bar if the meter is to be used in the lower position. A metric equivalent for this hanger bar has not yet been prepared.

Connectors

Connectors are used to join the metering cable to the hanger bar. The three most commonly used are designed to grip the cable securely without weakening or damaging either the outer layer or the inner core. The joint between the meter lead and the insulated copper core can be made both waterproof and secure in the body cavities of these connectors.

Sounding Cable

The current meter assembly is suspended by a single conductor electro-mechanical (co-axial) cable. The electrical circuit to and from the current meter is conducted through the insulated inner copper core and the double outer stainless steel layers of cable.

Depending on the size of weight to be suspended, either the 1/10" or 1/8" cable can be used. Normally, the larger cable is required only where weights in excess of 100 pounds are used regularly.

CAUTION

Premature failure of this cable will result if it is allowed to become kinked or if it is used with running sheaves that are smaller than those recommended by the manufacturer. The insulated inner core can easily be damaged if the cable is left unprotected on the drum of a sounding reel. A sharp blow from a hard object can cause the insulation to separate and result in an intermittent short circuit between the centre conductor and the outer cable.

7. Metering Frames

The purpose for a metering frame is to provide a support for a sounding reel and a means by which to suspend a meter and weight assembly from a bridge rail, a boat or a cable car. Various types are available and are manufactured from both wood and metal. Bridge metering frames are not normally used to support weights in excess of 50 pounds although the models made from metal can and have been used with weights of up to 100 pounds.

Some of the models are adjustable with provision for extending the boom, mounting the reel either in the centre of the frame for use from a boat or at one end for use from bridges. Others can be adjusted to fit across the sides of a boat or from the centre of a boat to a position over the bow.

Special frames have been manufactured for use from a sit down cable car to support large reels and heavy weights. These are normally stored at gauging station sites so that they are readily available when required.

8. Type A Crane

The Type A crane is intended to be used from bridges with weights up to 150 pounds and has been designed so that it can be easily dismantled for transporting. The boom has a reach of approximately 0.75 m from where it comes in contact with the bridge railing.

The crane can be mounted on a three wheel base or a four wheel truck, depending on the size of weight to be suspended. When fitted with the three wheel base, weights up to 100 pounds can be used. The crane is positioned with the two wheels close to the bridge rail so that when tilted to suspend equipment over the water, the crane is supported with the boom on the rail and the two wheels on the bridge deck.

The bridge rail is not required for support when the crane is fitted to the four wheel truck. A simple linkage system between the crane and truck is used to position the boom over and retrieve it from the railing. A number of counterweights are placed on the truck frame to offset the weight suspended from the boom.

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