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Hydrometric determinations — Unstable channels and ephemeral streams

Déterminations hydrométriques — Canaux non stables et cours d'eau éphémères

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 11332, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 1, *Velocity area methods*.

Introduction

This Technical Report presents methods that are particularly applicable to the gauging of streamflow in unstable channels and ephemeral streams. In this report, unstable channel refers to channels whose boundary condition of bed and banks frequently or continuously move so as to result in a progressively changing stage-discharge relation. This does not include instabilities resulting from aquatic growth. Reference is often made to sand-channel streams or to alluvial streams in this report. Many, but not all, unstable channels are of these types.

This Technical Report is not a substitute for other manuals of general procedures for gauging streams. Rather, it is a source of information, not generally included in stream-gauging manuals, that specifically addresses unstable channels and ephemeral streams.

The gauging of streamflow in unstable channels is considered, to some degree, an art and the techniques presented herein have been used successfully at specific stream-gauging sites. The good judgement of the technician is important when selecting techniques and procedures for gauging streams, because of the highly variable hydraulic characteristics along unstable channels and ephemeral streams.

Many channels, particularly in materials of small particle size, continually change configuration in response to flow. Because of the frequent and significant changing of the control, these channels are considered unstable (see 1.17 of ISO 772). The control changes are the result of scour and fill, changes in the configuration of the channel bed due to ripples, dunes, standing waves, antidunes and plane-bed formation, and channel braiding. The configuration of unstable channels can change appreciably in a short period of time; changes of bedform can occur in a few seconds. Changes in the control resulting from bed forms can be cyclic and vary with increasing and decreasing discharges. During high flow, multiple bed configurations across a channel are common. Dune beds alternating with plane beds along a channel have been observed moving down a channel.

The changing channel configuration and sediment deposition affects the sensing of stage at gauging stations. Stage sensors become isolated from the stream when channels migrate or scour and when sediment is deposited between the sensor and the flow. Sensors in contact with the flow wash away because of the difficulty of securing sensors in these unstable channels. Stilling wells fill with sediment and bubble-gauge orifices become covered with sediment. For convenience of access and construction considerations, sensors are often located on bridges and rock banks at constrictions where hydraulic conditions are not suitable for obtaining reliable records of stage or discharge.

Control changes resulting from causes such as the variation of energy gradient on rapidly rising and falling flood waves and from aquatic growth are not included in this report. Conditions such as these are also common in more stable streams.

A discussion of debris flows and translatory waves also are not included in detail in this report. Methods of computing discharge, such as the slope-area method (see ISO 1070), and the use of stage-discharge ratings do not directly apply to debris flows that are highly viscous, acting as a non-Newtonian fluid, nor to translatory waves. Debris flows and translatory waves do occasionally occur in ephemeral streams with unstable channels but the recording of stage and computation of discharge for those types of flows are beyond the scope of this Technical Report.

Hydrometric determinations — Unstable channels and ephemeral streams

1 Scope

This Technical Report deals with the measurement of stage and discharge and the establishment and operation of a gauging station on an unstable channel and/or ephemeral stream. It covers additional requirements and general considerations specifically related to sand-channel streams that are described in the measurement methods in the International Standards noted in clause 2.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 748:1997, *Measurement of liquid flow in open channels — Velocity-area methods*.

ISO 772:1996, *Hydrometric determinations — Vocabulary and symbols*.

ISO 9555-1:1994, *Measurement of liquid flow in open channels — Dilution methods for measurement of steady flow — Tracer dilution methods of steady flow — Part 1: General.*

ISO 9555-2:1992, *Measurement of liquid flow in open channels — Dilution methods for measurement of steady flow — Tracer dilution methods of steady flow — Part 2: Radioactive tracers.*

ISO 9555-3:1992, *Measurement of liquid flow in open channels — Dilution methods for measurement of steady flow — Tracer dilution methods of steady flow — Part 3: Chemical tracers.*

ISO 9555-4:1992, *Measurement of liquid flow in open channels — Dilution methods for measurement of steady flow — Tracer dilution methods of steady flow — Part 4: Fluorescent tracers.*

ISO 1070:1992, *Liquid flow measurement in open channels — Slope area method*.

ISO 1088:1985, *Liquid flow measurement in open channels — Velocity area methods — Collection and processing of data for determination of errors in measurement.*

ISO 1100-1:1996, *Measurement of liquid flow in open channels— Part 1: Establishment and operation of a gauging station*.

ISO 1100-2:—[1], *Liquid flow measurement in open channels — Part 2: Determination of the stage-discharge relation*.

1) To be published. (Revision of ISO 1100-2:1982)

ISO 1438-1:1980, *Water flow measurement in open channels using weirs and venturi flumes — Part 1: Thin-plate weirs*.

ISO 2537:1988, *Liquid flow measurement in open channels — Rotating element current-meters*.

ISO 3454:1983, *Liquid flow measurement in open channels — Direct depth sounding and suspension equipment*.

ISO 3846:1989, *Liquid flow measurement in open channels by weirs and flumes — Free overfall weirs of finite crest width (rectangular broad-crested weirs).*

ISO 3847:1977, *Liquid flow measurement in open channels by weirs and flumes — End-depth method for estimation of flow in rectangular channels with a free overfall*.

ISO 4359:1983, *Liquid flow measurement in open channels — Rectangular, trapezoidal and U-shaped flumes*.

ISO 4360:1984, *Liquid flow measurement in open channels by weirs and flumes — Triangular profile weirs*.

ISO 4366:1979, *Echo sounders for water depth measurements*.

ISO 4369:1979, *Measurement of liquid flow in open channels — Moving-boat method*.

ISO 4373:1995, *Measurement of liquid flow in open channels — Water level measuring devices*.

ISO 4374:1990, *Liquid flow measurement in open channels — Round-nose horizontal crest weirs.*

ISO 4375:1979, *Measurement of liquid flow in open channels — Cableway system for stream gauging*.

ISO 4377:1990, *Liquid flow measurement in open channels — Flat-V weirs.*

ISO/TR 7178:1983, *Liquid flow measurement in open channels — Velocity-area methods — Investigation of the total error.*

3 Definitions

For the purposes of this Technical Report, the definitions given in ISO 772 and the following definitions apply.

3.1 General terms for liquid flow measurement in open channels

3.1.1
gauge height of zero flow
GZF
highest point on the thalweg downstream from the gauge on a natural or artificial channel, relative to a gauge datum

3.1.2
thalweg
line of greatest depth and thus the lowest water thread, along the stream channel

3.2 General terms for the computation of discharge in unstable channels and ephemeral streams

3.2.1
antidune
bed form of curved symmetrically-shaped sand waves that may move upstream

NOTE Antidunes occur in trains that are in phase with and strongly interact with gravity water-surface waves.

3.2.2
discontinuous rating
rating that has a change in shape, commonly an abrupt change, that is the result of a change from lower to upper flow regime in all or part of the length of river acting as the control

3.2.3
dune
large bed form having a triangular profile, a gentle upstream slope, and a steep downstream slope

NOTE Dunes form in tranquil flow, and thus are out of phase with any water-surface disturbance that they may produce. They travel slowly downstream as sand is moved across their comparatively gentle, upstream slopes and deposited on their steeper downstream slopes.

3.2.4
flow regime
state of flow in sand-channel streams characterized by bed configuration of ripples, dunes, plane bed, standing waves and antidunes

NOTE Lower-regime flow is subcritical and upper-regime flow is super-critical (ISO 772:1996, 1.2).

3.2.5
GZF line
line on a shift diagram where the sum of the stage and the shift adjustment is equal to the gauge height of zero flow (GZF) for the rating

3.2.6
ripple
small triangular-shaped bed form that is similar to a dune but has a much smaller and more uniform amplitude and length

NOTE Ripple wavelengths are less than about 0,6 m and heights are less than about 0,06 m.

3.2.7
sand point
pipe with a well screen, underlying or adjacent to a stream, in which a gas-purge orifice is installed

NOTE The system usually has a device for flushing the sand point.

3.2.8
shift adjustment
correction made to the recorded stage that compensates for vertical movement or shifting of the control

3.2.9
shift diagram
curve or curves that expresses the relation between stage and shift adjustment for a given rating

3.2.10
standing waves
curved symmetrically shaped waves on the water surface and on the channel bottom that are virtually stationary

NOTE When standing waves form, the water and bed surfaces are roughly parallel and in phase.

4 Units of measurement

The units of measurement used in this Technical Report are those of the International System (S.I.).

5 Location of water level (stage) gauge

See 5.1 to 5.3 of ISO 1100-1:1996 for general principles and site characteristics.

5.1 Principles

For a stream with mobile boundaries, as with one having rigid boundaries, the best site for a stream-gauging station is in a long length of channel of uniform shape, slope and rugosity. Where the channel is the control, the gauge is located in the control reach of the channel and the site for high-water discharge measurements should be located near the gauge. This will permit the use of high-water current-meter measurements to define the characteristics of the stage-discharge relation. If an artificial control is installed, the gauge is located a short distance upstream from the control. If the channel in the vicinity of the gauge is suitable for the determination of peak discharge by the slope-area method (see ISO 1070), high-water current-meter measurements can be used to verify computed peak discharges.

In terms of a few years, or the life of many stream gauges, it is unlikely that the channel of many alluvial rivers will be stable because a precise balance is not maintained between their flow, sediment discharge, slope, meander pattern, channel cross-section and rugosity. For example, minor fluctuations in meteorological conditions over a few years can alter the flow of sediment in the drainage basin. During dry years, sediment can accumulate in stream channels and during subsequent wet years, the sediment is flushed from the basin. Both uniform and nonuniform parts of the stream channel may appear to be aggrading or degrading. Thus, there is no assurance that any length of channel on some alluvial rivers will remain stable over a period of a few years.

At a constriction on a sand-channel stream, the rating will be unstable because the constricted section will experience maximum streambed scour and fill. Except for channels with only a minor contraction, contracting stretches of a sand-channel stream are undesirable for use as a gauging-station site because of probable unstable hydraulic conditions. An opposite effect occurs, however, at a constriction on a stream with rigid boundaries because the control tends to be sensitive and stable. Often gauges on streams with unstable channels have been located at constrictions because of construction or access considerations; the ratings are unstable and may behave in a manner that seems to be unpredictable.

The gauging of streamflow may be particularly difficult where a channel is expanding, in a stretch with braided channels and where a channel is very wide and flat. The controls for these channels generally are insensitive and tend to be unstable. Also, records of water level for low flow are difficult to obtain because a low-water channel may move laterally across the wide stream channel leaving, the sensor isolated from low flows.

5.2 Water-level considerations

5.2.1 General

The continuous sensing of stream stage in unstable channels is often difficult mostly because (1) the flow may move laterally or vertically away from the sensor, (2) the sensor cannot be adequately secured and is easily-washed out, (3) the sensor may become inoperative because of sediment accumulation, and (4) the amount of surge the sensor is exposed to in an antidune or standing-wave environment may be very large. The cross-sectional shape of unstable channels is continuously changing and the stream can move away from a sensor at a fixed location; multiple sensors may be needed to monitor stream stage at these sites reliably. At streams with erodible banks, sensors may periodically need to be re-secured. Sediment accumulation around a sensor such as a pressure-gauge orifice can cause erroneous readings of stage and the stilling well can fill with mud. Sensors directly located in an upper-flow regime where there are standing waves or antidunes will be subject to violent surge; mechanical or electronic damping of the sensor signal may be required to obtain a readable record of water level.

5.2.2 Channels with stable banks

Bedrock outcrops on banks toward which the flow is directed by upstream conditions are good sites for sensors only from the standpoint that the sensor has a good chance of being in constant communication with low flows. Other factors such as pileup or drawdown in the sensor area or the generally unstable hydraulic conditions may outweigh the benefit of having the water in continuous contact at all stages with the sensor.

Generally, for streams with stable banks, a good location for a water-level sensor is on the outside or concave side, when viewed from within the channel, of very gradual bends of uniform channels. The thalweg of alluvial channels tends to be along the outside of bends and thus the sensor will be in contact with low flows and a wide range of stage can be sensed. During high flows, pileup may occur in the vicinity of the sensor, causing undesirably high recording of water level.

5.2.3 Channels with unstable banks

Straight uniform channels generally are good sites for sensors but some record may be lost during low flows when the water's edge moves away from the sensor and the sensor becomes disconnected from the stream. If the banks erode easily, the most secure locations are on the inside or convex side of gradual bends where a continuous streamward relocation of the sensor may be needed to keep in contact with the stream.

5.3 Discharge considerations

If a gauge must be located on a stream with an unstable channel, the effect may be lessened if the gauge is in a single uniform channel. A flat-floored vertically walled channel that resembles a rectangular laboratory flume may serve as a good gauging site because the results of research in such flumes, reported by several investigators, might assist the hydrographer in defining the rating. If the channel is relatively narrow the rating will tend to be sensitive and with a single-bed form across the channel rather than a less sensitive, more complex rating with multiple-bed configurations that are common across wide channels.

Steep-smooth channels where the Froude number exceeds 0,5 should be avoided if possible (ISO 1100-1:1996, 5.4.6.2). At Froude numbers of 0,5, the transition from dunes to rapid flow starts and the stage-discharge relation can be discontinuous and very unstable. For many sand-channel ephemeral streams, it is difficult to avoid high Froude numbers in part or all of the cross-section.

See clauses 5 and 6 of ISO 1100-1:1996 for methods that are suitable for measurements of discharge.

6 Stage measurements

See ISO 4373 for general requirements of stage-sensing devices.

6.1 Stilling wells

6.1.1 General

A stilling-well gauge consists of a float in a stilling well to sense stage. Stilling wells are located in the bank of a stream or are located directly in the stream and attached to bedrock banks, bridge piers, bridge abutments and other stable structures. For stilling wells in the bank of a stream, the water enters and leaves the well through a length of pipe (intake) connecting the well and the stream. The in-bank installation can be installed away from the higher floodflow velocities because the well and intake may be subject to filling and sealing from sediment accumulation, especially for ephemeral streams with unstable channels. Flushing systems to unclog intakes that apply water under a metre or more of head at the well end of the intake are often ineffective and difficult to use, particularly if the stream is dry and water for flushing must be transported to the gauge.

The most common and effective stilling well installation for unstable channels is achieved by locating the stilling well in the stream in direct contact with the flow. Intake holes should be normal to the flow as holes facing into the flow will create a higher stage in the well than in the stream; holes facing downstream will create drawdown and stages in the well will be lower than in the stream. If possible, the well should be located to avoid direct impact with large fast-moving debris and to avoid the lodging of drift and fibrous debris against the well. The bottom of the well should be more than 0,3 m below the maximum anticipated scour of the low-flow bed of the stream. Wells in direct contact with the stream can be serviced from outside the well using access doors at convenient intervals along the length of the well. Because the well can be serviced (sediment removal and inspection of floodmarks for example) through the access doors from outside the well, relatively small diameter wells can be used. Water enters and leaves the stilling well through holes in the side and/or bottom of the well.

6.1.2 Sediment deposition in wells

A problem common to all stilling wells on alluvial-channel streams with a large sediment load is sediment deposition in the well. For wells with a single intake, sediment-laden water enters the well when the stage is rising; the rises include general increases in stage and momentary increase of surges. The low velocities in the well allow the sediment to deposit in the bottom of the well. For wells with multiple intakes, additional deposition of sediment in the bottom of the well can result from eddy currents in the well induced by head difference at the intakes. The circulation of water laden with sediment between multiple intakes can bring large amounts of sediment into a well, with rapid deposition in the well.

Systems to flush sediment from intakes automatically and to prevent sediment-laden water from entering the well have been used. For example, on rising stages, sediment-free water from an external source can be automatically injected into the well using a system of valves and sensors. Also, an external source of water that is free of sediment, can be used to automatically flush intakes at regular intervals or during floodflow.

6.1.3 Sediment traps

For in-bank installations, stilling wells often fill with sediment, particularly those located in arid or semiarid regions on unstable channels. If a well is located on a stream carrying heavy sediment loads, it must be cleaned often to maintain a continuous record of stage. In those locations, sediment traps are helpful in reducing the frequency and labour of sediment removal.

A sediment trap is a large boxlike structure that occupies a gap in the lower intake line, streamward from the stilling well. The bottom of the sediment trap is usually about 1 m below the elevation of the intake. Inside the trap are one or more baffles to cause suspended sediment to settle in the trap, rather than pass into the well. A removable top to the trap provides access to the interior of the trap for periodic removal of trapped sediment.

6.1.4 Open-bottom wells

Wells located directly in the stream often have a bottom that serves as the intake. The bottom of the well is covered with some sturdy screen-like material that prevents the float from leaving the well. Some wells have a cone-shaped hopper bottom that serves as an intake. Open-bottom wells can be self cleaning if the bed of the stream scours below the well bottom during high flows.

Excessive surge in the stilling well can be reduced by reducing the number and size of the holes in the side and bottom of the well. A trial and error adjustment of intake holes can be used to achieve minimum surge, minimum sediment deposition in the well, self cleaning of the well, and sufficient flow of water into and out of the well to follow the rise and fall of stage without significant delay.

6.2 Gas-purge systems

6.2.1 General

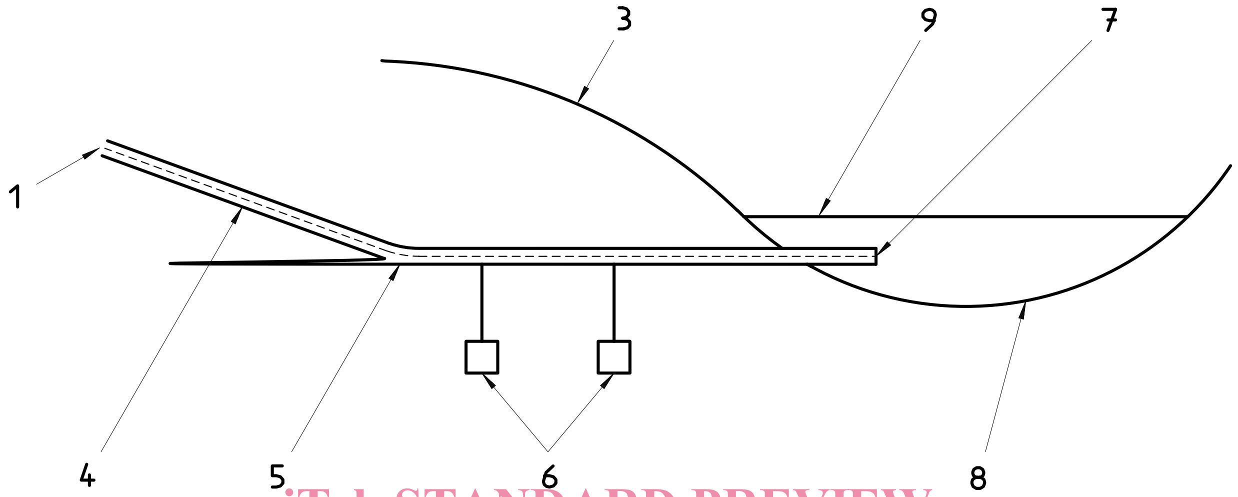
A gas-purge system (bubble gauge) transmits the pressure head of water at an orifice in the stream to a manometer, or pressure transducer, and recording device in a shelter. A gas, usually nitrogen, is fed through a tube and bubbled freely into the stream through an orifice at a fixed location in the stream [figure 1 a)]. The servo-manometer, or pressure transducer, and water-stage recorder converts the pressure signal to water stage. A major advantage of bubble gauges in unstable channels is that the orifice is small and relatively easy and inexpensive to relocate in the event the stream channel moves away from the sensor. See 6.2.3 for a discussion of manifold orifices.

Another advantage is that the orifice can be installed in a “muffler” or sand point under or adjacent to the stream in permeable material [figure 1 b)]. This installation avoids direct contact of the orifice with flow and eliminates the transverse effects of velocity head on the static head readings.

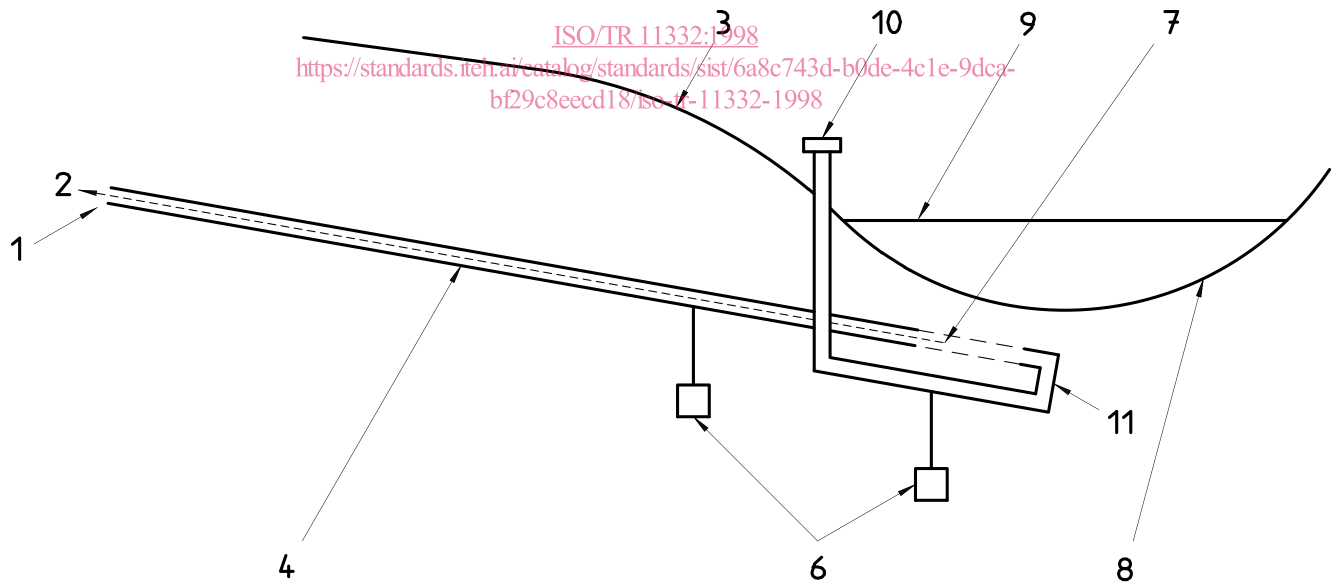
A disadvantage of the gas-purge systems is that the orifice can become covered with silt or fine sand and effectively sealed off from the head in the stream. Another disadvantage is that the system, particularly the servo-manometer is more complex than a stilling-well system. A bubble gauge can require more time to service and maintain and requires specialized training of operating personnel. See ISO 4373:1995, 8.1 for additional discussion of pressure gauges.

6.2.2 Anchoring of the orifice

The anchoring of the orifice and keeping the orifice in contact with the water in the stream are difficult at many sites with unstable channels. The intake pipe should be at right angles to the flow (see 6.1) and should be level or sloping downward from the manometer, or pressure transducer, to avoid accumulation of moisture in the pipe above the water level. The orifice should be anchored securely to avoid movement during high flow and it should be below the lowest stage to be recorded. For ephemeral streams with a high silt-clay load, the orifice should be installed above the channel bed to avoid covering and sealing of the orifice with silt and clay.



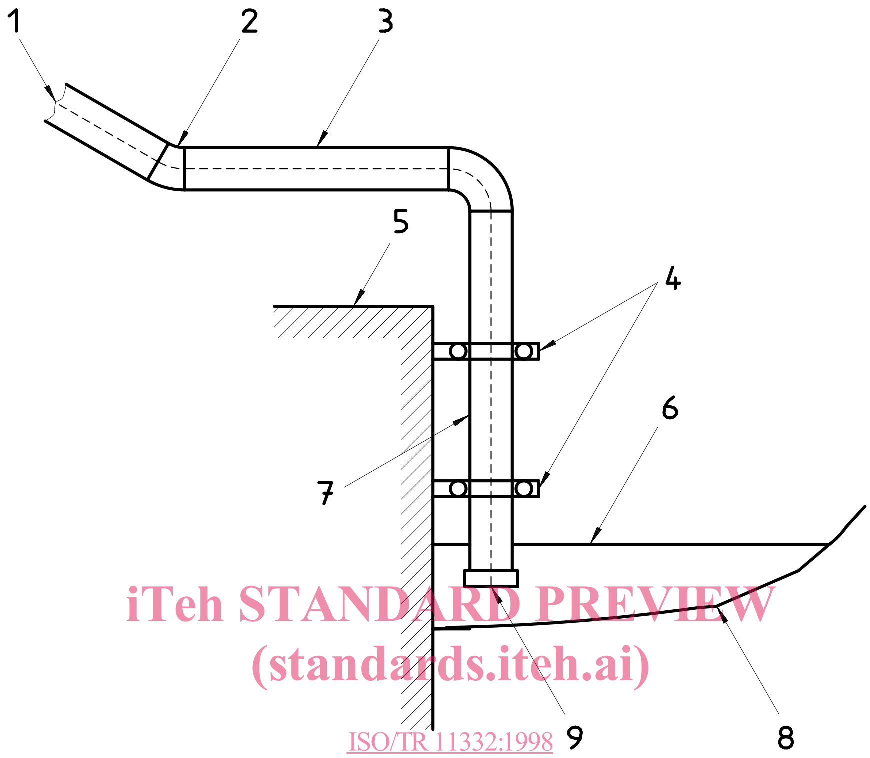
a) Orifice above the stream bed



b) Orifice in sand point below the stream bed

Figure 1 — Orifice installation in soft banks

An example of an orifice installation that can be adjusted to follow a streambed that scours and fills is shown in figure 2. The mounting brackets are loosened and the pipe, orifice, and bubble tube are raised or lowered to follow the streambed. When the elevation of the orifice of the bubble tube is changed, the new elevation must be determined and appropriate corrections made to the recorder or the data. This type of installation can be successfully used where the streambed scours or fills as a result of large floods.



Key

1 Gas line
2 Flexible joint
3 Pipe, 50 mm diameter
4 Adjustable mounting brackets
5 Concrete wall or rock bank
6 Water surface
7 Pipe with orifice can be raised or lowered to follow changing elevation of streambed
8 Silt-clay streambed
9 Orifice end cap

Figure 2 — Adjustable orifice installation

6.2.3 Manifold orifices

At streams that move laterally, a series of orifices can be installed across the channel, at bridge piers for example, and only the orifice that is in contact with the water is operated. The bubble tubes for each orifice are connected to a manifold for easy switching from one orifice to another. A single line connects the manifold to the manometer, or pressure transducer. Only one orifice is operated at a time and orifices can be activated and deactivated to follow the movement of the unstable channel. For many streams a manifold multi-orifice system can be much easier to operate than a single orifice that is manually moved to follow the stream.

6.2.4 Sand points and precautions

In sand and gravel channels, the orifice can be installed in a sand point beneath the stream bed. The orifice should be installed below the depth of maximum anticipated scour to avoid destruction when the bed scours during high flow. For streams where the ground-water level is higher than the stream surface, the head at a buried orifice will be slightly greater than the water surface of the stream and for a stream where the ground-water level is lower than the stream surface and with a saturated-flow connection between the stream and aquifer, the head at the orifice will be slightly less than the water surface of the stream. The head difference for an orifice located only 1 m or 2 m below the streambed in saturated sand and gravel will be insignificant for most gauges.

For normally dry streams perched above an aquifer, the initial flow by the buried orifice will be unsaturated and the head at the orifice will not be the same as the water-surface elevation of the stream. Until saturated conditions are achieved at the orifice, the head at the orifice cannot be accurately related to the stream stage. The entire stage hydrograph for large flash floods may not be recorded by a buried orifice located in an unsaturated flow environment.

Sand points do not perform well in streams with high concentrations of silt, clay, and fine sand, because the well screen becomes plugged with sediment. For streams with small concentrations of silt and clay, the well screen can be flushed with water during field inspections as shown in figure 1 b) or it can be temporarily cleaned by purging with gas. The orifice and well screen can be purged with gas at 1 MPa during field inspections or an automatic purge system can be used to purge at preset intervals. For high concentrations of silt, clay and fine sand, purging and flushing normally are ineffective and the orifice becomes sealed from the stream. Even with fine sands, the passage of water pressure from the river to the orifice can be so impeded as to cause a lag in the recorded stage. Thus, sand points are not recommended for streams with high concentrations of silt, clay, and/or fine sand.

Sand points require periodic servicing and cleaning to ensure satisfactory operation. The sand point should be removed from beneath the streambed and the well screen cleaned or replaced at least every two years. More frequent servicing and cleaning will be needed for sand points in many streams. In general, the more silt and clay in the stream and the more chemical reaction of the well-screen material with substances in the water, the more frequently will servicing be needed. The main advantage of orifice sand-point installations is that the sensor is relatively inexpensive and can be installed under the streambed free from damage by vandals and flood flow. Also, the stream can move laterally and vertically one or more metres without affecting the reliability of the record. These advantages can be offset by clogging of the well screens and the frequent maintenance needed to keep the equipment operating.

6.3 Problems with water-sediment densities

The density of the water and sediment mixture may increase as the result of increased suspended-sediment concentration. Because the manometer senses pressure at the orifice, the pressure or head will be affected by the change in density of the fluid. To a lesser degree for most streams, the density of water will also change due to variation of water temperature and chemical content. With the possible exception for large fluctuations in stage and large changes in suspended-sediment concentration, the density correction can be ignored. For high-head installations, the effects of temperature can be compensated for by using a temperature-compensated manometer. If the density of water consistently increases linearly with stage, the manometer can be adjusted to compensate for the effect (see ISO 4373:1995, 8.1.2.1).

6.4 Acoustic systems

Acoustic distance meters are installed above the stream to sense stream stage continuously. The non-contact sensor generally is within 10 m of the water surface, and an average stage over a period of a few seconds is obtained. The sensor shall be rigidly mounted over the stream. Because the speed of sound varies with air temperature, temperature compensating meters are recommended for most sites. Acoustic distance meters with monthly calibration can provide a record of stage reliable to within 30 mm.

6.5 Wire-weight gauges

A commonly used wire-weight gauge consists of a drum wound with a single layer of cable, a bronze weight attached to the end of the cable, a graduated disc attached to the drum shaft, and a counter. The gauge is mounted on a bridge handrail, parapet wall, pier or some other rigid structure over the stream for use as an outside gauge. The bronze weight is raised or lowered by turning the drum. The gauge is set so that when the bottom of the weight is at the water surface, the gauge height is indicated by the combined readings of the counter and the graduated disc.

Reliable readings of stream stage are obtained with a wire-weight gauge where there is little surface disturbance and the velocities are not great. For high velocities with turbulent surges or where there are dunes or antidunes, it is difficult to determine the mean stage because the weight is carried downstream and the water surface is undulating too rapidly to obtain reliable readings of maximum and minimum stage. Reliable measurements of stage on steep streams with unstable channels generally cannot be obtained with a wire-weight gauge (see ISO 4373:1995, 7.4.5.2).